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CONTENTS

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THE BIOLOGY AND CONSERVATION OF ACROCHORDID SNAKES

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ABSTRACT: In this paper I provide a brief overview of the biology of acrochordids, and I propose that conservation efforts be undertaken to curb the rising levels of human exploitation of these species.

INTRODUCTION

The Acrochordidae are among the more remarkable of living snake fauna and exhibit many fascinating and novel features of morphology, physiology and natural history. They appear to have a very early and primitive origin, but their phylogenetic relationships with other snakes are unclear (e.g., McDowell, 1979). Members of the Acrochordidae have evolved numerous specializations and share certain of these with diverse taxa of other snakes. In many respects these snakes are poorly studied although they are of immense scientific interest and probable ecological importance.

GENERAL DESCRIPTION AND DISTRIBUTION

Acrochordidae is a family of aquatic snakes consisting of three species belonging to a single genus. A fourth extinct species is known from the upper Miocene and lower Pliocene of Pakistan (Hoffstetter and Gayrard, 1964). The morphology of the three living species is so different from that of other snakes that they have been joined in a separate superfamily, the Acrochordoidea (McDowell, 1979).

Acrochordus granulatus, the filesnake or little filesnake, is the smallest of the three species and reaches a maximum length of about one metre. Originally, this species was placed in a separate genus *(Chersydrus)* and thought to be venomous. For convenience, I will follow Schlegel (1837), Smith (1943) and McDowell (1979) who include *Chersydrus* in the genus *Acrochordus*, although some others have maintained them as separate genera (e.g., Hoffstetter and Gayrard, 1964). The range of *A.granulatus* extends from the western coast of India through tropical Asia to the Philippines, south to Timor, and east to New Guinea, northern Australia, Bismarck Archipelago and the Solomons. It is found in the sea but typically in mangroves or other areas of shallow water (fig 1). Voris and Glodek (1980) routinely captured these snakes 2-10 km from shore at depths of 4-20 m, which is probably the maximum depth for this species. Throughout the range of the species, populations of *A. granulatus* enter rivers and are known from freshwater lakes in New Guinea and in the Philippines. The inland distribution of this species in rivers and lakes is probably limited by waterfalls, not tolerance to freshwater (McDowell, 1979).

The other two species of acrochordids are larger than *A. granulatus* and resemble each other in general body form. *Acrochordus javanicus*, the elephant's trunk snake or wart snake, grows to a maximum length of a little under 2 m (fig 2). It ranges from Thailand through Malaysia and the Greater Sunda Islands of Indonesia. It is largely an inhabitant of streams, lagoons and other areas of permanent freshwater, but also enters estuaries and the sea. Permanent marine residence is unlikely, however, and this snake should be considered a freshwater species.

The arafura filesnake, *Acrochordus arafurae* (Fig. 3), appears confined to the freshwater drainages of New Guinea and Australia connected to the Arafura Sea, including the Gulf of Carpentaria. Its maximum length is about 1.7 m (McDowell, 1979).

MORPHOLOGICAL SPECIALIZATIONS

Several features of acrochordid anatomy may be interpreted as adaptations for aquatic life and

piscivory (see below). Valved nostrils are located at the dorsal aspect of the snout to enable air-breathing while virtually the entire body remains underwater (Fig 3a). The tail of *A.granulatus* is compressed laterally to assist swimming (Fig. 1), although this feature is not developed as extremely as in sea snakes. The loose skin and supple musculature also enhance mobility by enabling pronounced lateral compression of the rear aspect of the body. The flabby skin, roughened by numerous tubercles projecting from numerous small scales(Fig. 3b), enables these snakes to seize and hold struggling fish (Dowling, 1960). The vertebrae are relatively short with a small condoyle that is partially freed for the flexibility requirements of swimming (Johnson, 1955). The skull, too, is flexible with elongate quadrates and an unusual quadrate-columella articulation apparently ideal for swallowing fishes (Savitsky, 1983).

The skin of acrochordids is unusually specialized and bears sensory organs that are prominent and innervated (Schmidt, 1918; Price, 1982; A. Savitzky, R. Ruibal, unpublished observations), Sensory organs of the scales consist of a projecting dome of epidermis associated with a bundle of epidermal bristles similar to sensory structures found in some lizards. The base of this structure is innervated. In addition, the interstitial skin between the scales is developed into bristle-bearing tubercles that also appear to be sensory. These complex sensory organs are presumably useful in relation to movement, orientation and capture of fish in waters where visibility may be extremely limited.

In terms of soft anatomy, the more distinctive features of the acrochordids are a mid-body location of the heart, a lung that exhibits vascular parenchyma for its total length throughout the body cavity, and capacious veins that may be engorged with unusually large volumes of blood. A sublingual salt gland is present in *A. granulatus* (Dunson and Dunson, 1973).

PHYSIOLOGICAL ADAPTATIONS

Studies of acrochordid snakes by several authors have shown them to be highly specialized for prolonged submergence in shallow, aquatic habitats. All three species appear to exhibit unusual metabolic, respiratory and cardiovascular adaptations.

Patterns of lung ventilation and rates of oxygen uptake have been measured in all three species of acrochordids (Glass and Johansen, 1976; Seymour et al., 1981; Lillywhite and Smits, 1985;). Oxygen consumption varies from about 0.2 to 0.4 ml/g•h and is considerably lower than that of many other snakes and roughly one-half that of reptiles generally. Partitioning respirometry studies indicate that a fraction of gaseous exchange is cutaneous. Oxygen consumption and CO_2 release through the skin are as much as 8% and 33%, respectively, in *A. javanicus* (Standaert and Johansen, 1974), and 24% and 76% in *A. granulatus* (Lillywhite and Smits, 1985; unpublished data). When the latter snakes are in hypoxic water, pulmonary oxygen uptake increases to make up for the reduction in oxygen transfer across the skin.

Laboratory studies of *A. arafurae* suggest that acrochordids have low capacities for aerobic and anaerobic energy production and cannot sustain vigorous activity for more than a few minutes (Seymour et al., 1981). Low levels of myoglobin and low specific activities of metabolic enzymes in skeletal muscle point to low rates of oxygen uptake and (or) low levels of lactic acid production by tissues, even during activity. Fatigue occurs rapidly in spite of high circulating oxygen reserves, and blood lactate levels are also low and characteristic of other snakes at rest.

Typically, *Acrochordus* remain submerged for long periods and rest on submerged substrates between bouts of breathing (Smith, 1914). A ventilatory period typically consists of several breaths spaced over a period of 5-10 minutes (see figures in Glass and Johansen, 1976; Seymour et al., 1981; Lillywhite and Donald, 1989). During breathing the snake rises to the surface and breaks water only with the external nares. After a single breath is taken, the snake withdraws the

FIG. 1 :Coastal mangrove habitat of Acrochordus granulatus at Bais Bay, Negros, Philippines

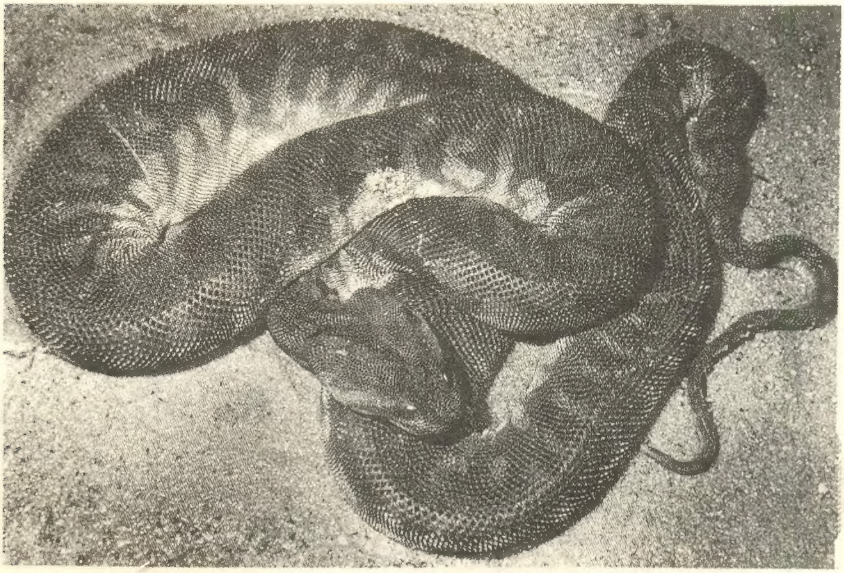

FIG. 2 : Adult specimen of Acrochordus javanicus showing (a) features of the head and (b) spinous nature of the body scalation. Photographs courtesy Alan Savitsky

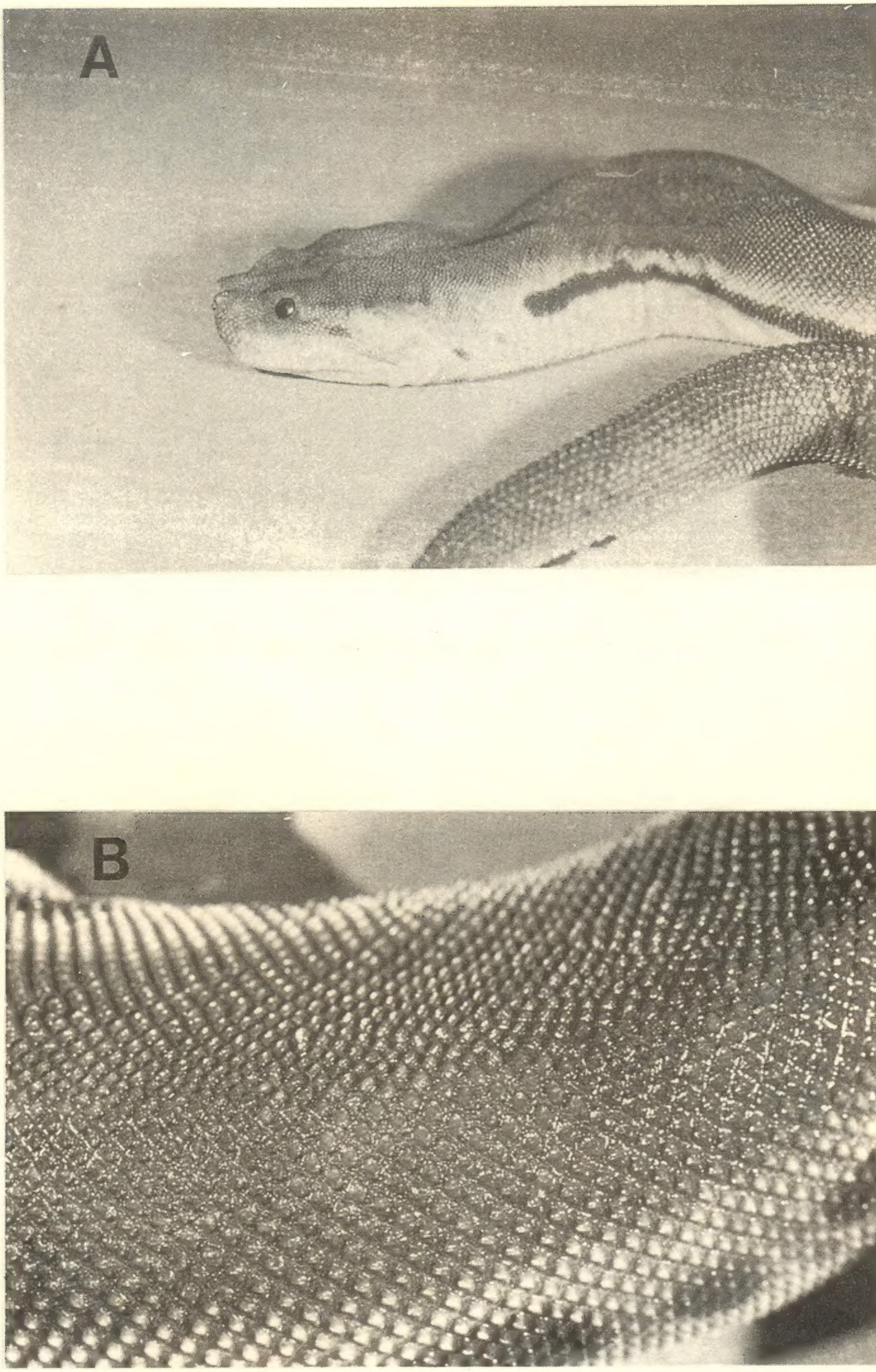

FIG. 3 : Adult specimen of Acrochordus arafurae. Photograph courtesy of Richard Shine

head just below the surface, holds its position there for 1-2 minutes, then breaks water again for another breath. This pattern is repeated until the end of the ventilatory period at which time the snake returns to the bottom of the water column. The spacing of several breaths over the 5-10 minutes ventilatory period apparently serves several related purposes. It allows the lung gases to reequilibrate with air; CO_2 stores are released; and the blood becomes saturated with oxygen. Renewal of the blood oxygen store is enhanced by a dramatic increase in the pulmonary blood flow during ventilatory periods (Seymour et al., 1981; Lillywhite and Donald, 1989).

Laboratory studies of freely diving snakes and perfused lung preparations have shown that pulmonary blood flow is regulated by an interplay of adrenergic vasodilation and cholinergic vasoconstriction within a densely innervated lung vasculature (Lillywhite and Donald, 1989). Typical patterns of circulation involve alternating peak blood flow between the lung and systemic vessels during the dive cycle. Blood flow completely bypasses the lung for intermittent periods during long, undisturbed dives, then increases greatly in the pulmonary circuit during bouts of ventilation when the flow of blood may largely bypass the systemic circulation. These reciprocating patterns of preferential perfusion reflect inverse relations between flow and vascular resistance, with the result that arterial pressures remain essentially constant throughout the blood circulation during repetitive dive cycles. Resting heart rates are reduced to 4 or 5 bpm during late stages of a dive, then increase to 20-30 bpm during short breathing episodes when the oxygen stores are renewed. Patterns of blood circulation in diving *Acrochordus* reflect an unusual ability to shunt blood from pulmonary to systemic circuit (or vice versa) and provide a potentially useful and important model for studies of neurovascular regulation of the lung.

Filesnakes dive following inspiration. In *A. granulatus*, the lung oxygen store is roughly equivalent to that in the blood (unpublished data). The lung of acrochordids is elongate and bears functional parenchyma the entire length of the body cavity. The blood oxygen stores of *A. granulatus* are unusually large owing to a combination of large blood volume (about 13% of body mass) and high concentration of red blood cells (mean hematocrit about 50%) (Feder, 1980; Lillywhite et al., 1988). Thus, the oxygen capacity of the blood is about 20 vol%, which is two or more times greater than that of other reptiles and roughly comparable to that of endothermic birds and mammals (Lillywhite et al., 1988).

The oxygen stores are theoretically sufficient to sustain aerobic dives for 1.5-2 h (minimally). This corresponds to observed dive times of *A. granulatus*, although some individuals remain submerged for periods as long as 3-5 h (Lillywhite and Smits, 1985; Lillywhite and Donald, 1989). Published dive times of the other species are somewhat shorter, probably because the observations were made in open aquaria in which snakes reduce their lung volumes so as to remain neutrally or negatively buoyant while resting on the bottom. However, if snakes are provided with objects in which, or beneath which, they may conceal themselves, they will remain submerged with larger lung volumes even if positively buoyant because they are effectively "anchored" with respect to the water column (unpublished observations).

The near complete utilization of the oxygen stores is quite different from the situation found in routine diving patterns of other marine reptiles (Seymour, 1982) and is dependent on a suite of physiological specializations. One of the more important is the possession of a hemoglobin that has a very high affinity for oxygen and is also quite sensitive to changes in blood pH. The high affinity of the hemoglobin allows the blood to saturate at relatively low partial pressures of oxygen and favours uptake of oxygen from the lung and (via the skin) ambient water. Although cutaneous losses of CO_2 tend to reduce its partial pressure in blood, the long breathholds characteristic of these snakes simply override this tendency with the result that levels of PCO_2 in blood are actually comparatively high (Seymour et al., 1981; H. Lillywhite, A. Smits, M. Wheatly, unpublished data). Low blood pH attributable to increasing levels of CO_2 load

during prolonged submergence reduces the oxygen affinity of hemoglobin and allows delivery of oxygen to tissues at very low levels of PO_2.

Acrochordus granulatus can tolerate a range of water salinity from freshwater to sea water. A sublingual salt gland is presumably important to osmoregulation in marine habitats (Dunson and Dunson, 1973). The other freshwater species are able to tolerate a range of fresh and brackish water conditions.

Data on body temperatures of acrochordids are limited, but all three species are almost certainly passive thermal "conformers" and assume temperatures of the warm tropical waters in which they occur. In most of the aquatic habitats in which these snakes occur, limited thermal heterogeneity greatly reduces the opportunities for active thermoregulation. Telemetry studies of body temperatures in *A. arafurae* indicate that body temperatures are highly correlated with water temperature and vary in parallel with diurnal and seasonal fluctuations of water temperature. However, the variance of body temperatures is lower than that of water temperatures, which suggests that limited thermoregulation may occur (Shine and Lambeck, 1985). This departure from exact thermoconformity presumably reflects selection of suitable thermal microhabitats by the telemetered snakes.

Body temperatures of *A. arafurae* average 26°C in the dry season and 30°C in the wet season (Shine and Lambeck, 1985). Water temperatures in mangrove habitats occupied by *A. granulatus* suggest that body temperatures of this species extend over a similar annual range (H. Lillywhite and M. Feder, unpublished observations). It is interesting to note, however, that surface waters in shallow mangroves may reach daytime temperatures in excess of 38°C during the warm season. Snakes appear less active during these daytime periods and are largely secluded inside burrows in the substratum (and probably among mangrove roots) where temperatures are cooler. The snakes presumably experience the high temperatures briefly during bouts of breathing, however.

ECOLOGY AND BEHAVIOUR

Because of their aquatic and reclusive habits in tropical environments, filesnakes are difficult to study. The most extensive ecological information has come from recent investigations of *A. arafurae* by Shine and his co-workers in tropical Australia (Shine and Lambeck, 1985; Shine 1986a,b,c). There is very limited information on *A. granulatus* (Voris and Glodek, 1980; Gorman et al., 1981), and on *A. javanicus* (Dowling, 1960; Boo-Liat, 1964; Lim 1964).

All three species of filesnakes appear to be nocturnal: activity is more intense and movements are more extensive at night than during the day (Lim, 1964; Pough, 1973; Shine and Lambeck, 1985; Lillywhite, unpublished observations). Although physiological investigations have emphasized the sluggish behaviour of these snakes, telemetry studies of *A. arafurae* demonstrate a consistent trend for extensive daily movements (Shine and Lambeck, 1985). The daily nocturnal displacement of these snakes during the wet season averages 141 m, and calculated home ranges (0.06-4.68, mean 1.31 ha) are larger than those reported for most other snakes. However, because of their low metabolic rates and the low energy requirements for swimming, it is likely that the energy expenditure for locomotion is quite low in filesnakes, in spite of the distances covered.

The nocturnal movements of filesnakes appear largely related to foraging. The author has observed *A. granulatus* patrolling shallow pools created at low tide and serving to concentrate fishes. Filesnakes feed almost exclusively on fish, and prey include a wide variety of species and sizes as well as carrion (Shine, 1986a). Sleepy cod *(Oxyeleotris lineolatus)* and barramundi *(Lates calcarifer)* comprise the more important prey items by weight in *A. arafurae* (Shine, 1986a). *Acrochordus granulatus* appear to specialize on gobiid and goby-like fishes (Voris and Glodek, 1980), although stomach contents suggest that crustaceans may be eaten occasionally (Cogger, 1975; McDowell, 1979). *Acrochordus*

javanicus may be eaten occasionally (Cogger, 1975; McDowell, 1979). *Acrochordus javanicus* may specialize on freshwater eels *(Fluta alba)* and catfishes in Malaysia (Lim, 1964). Observations of my own and others (Dowling, 1960; Shine, 1986a) indicate that filesnakes are constrictors in the sense that the body is wrapped around fish to subdue and hold them. Prey are captured either with the mouth or by rapid entrapment in body coils, and as mentioned, the rough tuberculate skin enables the snake to hold onto its prey. Fish are swallowed very rapidly, possibly serving to minimize the ingestion of water. Captive snakes tend to feed more readily and can capture fish more easily in shallow than in deep water. Whether foraging is related to tidal cycles in coastal habitats is unclear, but this hypothesis should be investigated.

Data on the proportion of snakes containing prey items at the time of capture suggest that feeding rates are low in acrochordids compared with other taxa of snakes (reviewed in Shine, 1986a). The low proportions suggest that filesnakes may feed infrequently and that energy requirements are low. Very limited data provide the inference that growth rates are also slow (Shine, 1986a).

The extent and nature of aquatic habitat occupied by filesnakes may change dramatically in relation to tidal and precipitaton regimes. In northern Australia where precipitation shows strong seasonality, Shine and Lambeck (1985) have documented habitat shifts of *A arafurae* from billabongs to shallowly-inundated grassland during the wet season. Such movements are possibly in response to similar shifts or movements of prey, but this possibility requires further study. When the waters recede, some of the snakes can become entrapped in drying ephemeral pools (Shine and Lambeck, 1985). Although this species has never been reported to be seen out of water, individuals trapped in such pools conceivably travel overland to return to the main watercourse. Based on escape attempts by captive specimens, these snakes could potentially travel hundreds of metres overland.

Although nearly all published references to acrochordids state that they are strictly aquatic, there may be many situations where these snakes are forced to leave the water. Worrell (1963) reports that *A. granulatus* are frequent on salt water mud flats at low tide and shows a photograph of a dead specimen. Heatwole reports finding the same species on mud flats in Papua New Guinea, and I have observed these snakes crawling through extremely shallow tidal pools on mud flats in the Philippines. Thus it seems likely that snakes sometimes leave water to travel from pool to pool or to main watercourses during periods of low tide.

Filesnakes generally occupy water that is relatively shallow, although *A. granulatus* have been captured in waters up to 20 m deep (Dunson and Dunson, 1973; Voris and Glodek, 1980). Although *A. granulatus* occur on shallow reefs, they are more characteristic of shallow mangroves where they hide among mangrove roots and inside holes and burrows that occur on the substratum. In captivity, these snakes will bury themselves in mud if the soil particles are not too coarse (unpublished observations). *Acrochordus arafurae* tend to shelter beneath trees that overhang the water's edge and also utilize floating grass mats during the dry season when other vegetative cover is sparse or lacking (Shine and Lambeck, 1985). In general, *A. arafurae* seem to prefer heavily vegetated shallow-water areas whenever these are available. *Acrochordus javanicus* are reported to burrow in river banks under the roots of trees where they are sometimes found in large aggregations (Lim, 1964).

Selection pressures related to behavioural and physiological adaptations for prolonged diving are conceivably related to predation vulnerability in shallow water. Little is known concerning predation pressures on filesnakes, but *A. arafurae* are occasionally eaten by crocodiles and are heavily hunted by white-breasted sea eagles, *Haliaetus leucogaster,* when they surface to breathe (L. Corbett, as cited in Shine and Lambeck, 1985). Snakes are presumably less vulnerable to predators (particularly avian predators) when they remain submerged and hidden in shaded water. Very limited mark-and-recapture data indicate that at least some file-

snakes remain in the same area year after year (Shine, 1986a).

REPRODUCTION AND POPULATION BIOLOGY

Published data on acrochordids indicate that reproduction is seasonal but far less frequent than in most other snake taxa studied. Among samples of *A. arafurae* studies by Shine (1986a) the proportion of adult-sized females that were reproductive ranged from 4 to 25% and averaged only 7%. Moreover, data from dissections showed that less than 15% of non-gravid females have enlarged oviducts or ovaries indicative of reproduction the previous year. Data on the other filesnake species are more limited but suggest that they also reproduce infrequently (Boo-Liat, 1964; Gorman et al., 1981., H. Lillywhite, unpublished data). A review of published literature indicates that reproductive frequencies in other snake taxa are rarely less than once per three years, and, indeed, the majority of adult-sized females generally reproduce annually (Shine, 1986a; Seigel and Ford, 1987; and references therein). In strong contrast, it appears most probable that female *A. arafurae* reproduce only once every 8-10 years (Shine, 1986a).

Fecundity of *A. arafurae* averages about 17 young (extremes 11-25) and is correlated with female body size (Shine, 1986a). Neonatal snakes are relatively large, and relative clutch mass (defined as offspring weight divided by weight of the female without offspring) averages 0.53 in captive snakes. Observed litter sizes vary from 11 to 32 (Shine, 1986a and references therein). Relative clutch mass (0.19: Voris and Glodek, 1979) and litter size (4-12: Wall, 1921; Smith, 1943) are both smaller in *A.granulatus* than in *A. arafurae*, in part attributable to size differences between the two species. Between 40 and 50 eggs evidently have been found in a female *A. javanicus* (Tweedie, 1983), although this information requires confirmation and may not be typical.

There is very little information available on population densities of acrochordids, although field observations suggest that numbers may vary from few to very high densities in different areas. Mark and recapture estimates indicate that populations of *A. arafurae* may reach levels as great as 100 snakes/ha, representing a biomass density exceeding 50 kg/ha (Shine, 1986a).

HUMAN EXPLOITATION AND CONSERVATION

At present it is difficult to know the impact of human activities on filesnakes. The aquatic and secretive habits of these snakes probably minimize their contact with humans. On the other hand, local abundance of populations, sluggish movements, and the need to breathe air periodically render filesnakes vulnerable to exploitation. Regarding the conservation of these reptiles, there are two general areas of concern. One is the direct exploitation of snakes by hunting and inadvertent killing; the other is the indirect destruction attributable to depletion of the quantity and quality of habitat.

I originally became interested in the conservation status of filesnakes when, during the course of several research trips to the Philippines during the 1980's, I noticed the gradual appearance of more and more handcrafted products made from skins of *A. granulatus*.The black-and-white banded skin of this species is attractive and probably will assume increasing importance among skin products as larger species of snakes become increasingly rare. The skin of *A. javanicus* is used for making ornamental leather, which is called "karung", and this species is commonly exported from the Indonesian archipelago. There is no doubt that filesnakes generally are collected for the skin trade, but I am unaware of any data to indicate how widespread or intensive such exploitation has become. The hunting or sale of filesnakes and their products is prohibited by law in some countries where these snakes are common. However, throughout much of Asia such protection is either absent or ineffectively enforced. Many consumer countries continue to import reptile skins and products because once items made from species not listed by CITES are successfully smuggled out of an area, they can be legally imported into many countries without documents from the country of origin. Moreover, tourists appear willing to buy and export reptile products as

long as a retail market and lack of enforcement at export points continue.

Filesnakes are collected for the pet trade as well as for products. *Acrochordus javanicus* has been the principal target of animal dealers, but I have seen *A. granulatus* in pet stores recently in Florida. This seems particularly tragic because most, if not all, persons who buy such snakes will not have sufficient knowledge to properly care for them.

Other forms of exploitation threaten filesnakes in addition to harvesting for commercial purposes. Activities related to agriculture and fishing can be harmful to snakes in certain areas. For example, *A. granulatus* and other aquatic snakes are frequently caught in fishing nets used by fishermen in the Chilka Lake region of Orissa (Dutta, 1989). The fishermen generally use nets with small mesh for catching prawns, and snakes (particularly *Cerberus rhynchops*) appear to be attracted to the trapped prawns and fish. The heads of the snakes get caught in the mesh and are squeezed, pulled or crushed when the fishermen extract the snakes from the nets. It is also likely that people in some areas kill filesnakes that are accidentally encountered, simply out of fear or ignorance. Such killing is expected to have little impact on populations, however.

In Australia *A. arafurae* are selectively hunted by aboriginal people who utilize them as a food resource. Filesnakes are actually quite popular items in certain regions where they are collected by groping under logs and among *Pandanas* roots (Shine, 1986b). This method is most effective when waters have receded in the dry season when female snakes are gravid. Because of the pronounced sexual dimorphism which characterizes arafura filesnakes, the larger females are more easily found and seized in the turbid waters than are males and smaller snakes. The selected predation on adult females, some of which are gravid, potentially reduces the reproductive output of the snake population. However, there is no evidence that such predation on filesnakes by aborigines is having any significant effect on the populations of these snakes. The snakes appear to be numerous, and the numbers of people hunting them are relatively small. It is important to emphasize, however, that aboriginal predation is related to subsistence rather than commercial exploitation of the wildlife resource.

Finally, destruction of mangroves, damming of rivers, drainage and physical disturbance of wetlands, and various forms of water pollution all pose serious threats to filesnake populations. The impact of such disturbance on the distribution of acrochordids is almost totally unknown and in need of evaluation.

SUMMARY AND RECOMMENDATIONS

Sufficient information is available on acrochordids to indicate that the three species share many remarkable attributes which render them quite different from many other snakes. Physiologically, filesnakes are characterized by a suite of specializations that confer low metabolic rates, cutaneous as well as pulmonary exchange of respiratory gases, and both efficient utilization and rapid recovery of large oxygen stores. These snakes are adapted for prolonged submergence in shallow-water habitats – diving behaviour which minimizes contact with aerial predators and high temperatures of thermally stratified waters. Several morphological features are related to aquatic specializations, including midwater capture of fish and the ability to move around and orient on complex substrates in murky water. Acrochordids appear to be "low-energy specialists" (Shine, 1986a) which consume and utilize energy at low rates. Consequently, growth and reproduction are slow. Because of their low demands for energy and the utilization of carrion, acrochordids probably have insignificant economic impact on fish populations or communities. However, because they are almost exclusively piscivorous and are near the top of aquatic food chains, they could possibly serve as sensitive indicators of the health of ecosystems such as mangroves.

Because of slow growth rates and low reproductive frequencies, filesnakes are predicted to be particularly sensitive to harvesting by humans for commercial purposes. Thus it is imperative that research and management efforts be undertaken to monitor the size and dis-

tribution of filesnake populations and to prevent their depletion. While some may assume that these snakes are common, widespread and in no danger of overexploitation, there really is a cogent need for systematic surveys on the abundance and distribution of populations to confirm or reject this supposition and to serve as a base for future monitoring efforts.

The most serious threats to filesnakes appear to be habitat destruction and the hunting of snakes for the skin trade. The destruction of aquatic and wetland habitats affects all regional wildlife and is perhaps best dealt with by a broad range of efforts related to conservation strategies generally. The marketing of reptilian leather goods affects many species of snakes in addition to the acrochordids. Although it represents a difficult challenge, efforts should be undertaken to achieve international cooperation in reducing the demand for snakeskin products which can easily be replaced by substitute leathers from domesticated animals. Without increased efforts to protect habitat and to reduce the hunting of snakes for the skin trade, filesnake populations will be adversely affected and local extinctions will occur.

Motivation to stimulate interest in the conservation of acrochordid snakes arises in part from a natural history perspective which places extreme value on the many evolutionary innovations and potential scientific value of these species. Perhaps an important strategy for the long term conservation of these animals is to educate people, especially the younger generation, about the fundamentally fascinating biology of these snakes.

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THE SOCIAL HIERARCHY OF THE WATER MONITOR, *VARANUS SALVATOR*

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ABSTRACT: Water monitors of both genders and all age classes will organise themselves into a dominance hierarchy. This is based upon aggressive behaviours involving the characteristically sharp teeth and claws. Animals of inferior status respond to aggression with flight, whereas lizards of similar rank typically respond with warning displays and will fight if the aggressor persists in offence. The largest individuals tend to be the highest ranking, irrespective of their gender. Water monitors probably have some ability to recognise other members of the local hierarchy in order to quickly respond in a manner appropriate to their social status. Aggressive interactions are undoubtedly detrimental to the monitors' health. In order to maximise 'output' in captive breeding programmes for this species, such interactions should be minimised through careful attention to enclosure design, stocking density and feeding regime.

INTRODUCTION

There have been a number of studies on the Varanidae which reveal that lizards of this family demonstrate remarkably complex social behaviours (Auffenberg, 1981a, 1981b, 1988; Davies et al, 1986). In addition to courtship interactions, this repertoire of interspecific behaviours includes acts which establish and maintain social hierarchies within the local population (Auffenberg, 1986).

This report is intended to introduce how social hierarchy is manifest in the water monitor, *Varanus salvator* - a little-studied species. This large, semi-aquatic varanid has a widespread distribution, from India and Sri Lanka in the west to the Philippines and Sulawesi in the east. The species is declining throughout much of this range due to habitat loss and hunting (Whitaker and Whitaker, 1978; Das, 1989). A better understanding of its social behaviour may be of use in efforts to conserve the water monitor - in particular with respect to captive breeding programmes.

MATERIALS AND METHODS

The study subjects were 17 water monitors which occupied a single outdoor enclosure at the Madras Crocodile Bank in Tamil Nadu, South India (12 50'N, 80 10'E). This group comprised captive-bred juveniles hatched in 1989; snout-vent length [SVL] = 31.0 to 39.0cm), two year olds hatched in 1988; SVL = 42.0 to 53.5cm) and an adult wild-caught male of unknown age (SVL 120cm)(Andrews and Gaulke, 1990). At least some of the two year olds had already matured, but no courtship or nesting behaviour was observed during the study period. The monitors could be distinguished primarily by means of varying numbers of notches cut into the dorsal edge of their tails.

The monitor enclosure consisted of a shady circular pit of 5.73m diameter, containing a large S-shaped pond. 75% of the land was exposed sand; the remainder was grassed, with trees (which the monitors were unable to climb because there were broad metal collars around the trunks), branches and small piles of rocks. All of the lizards could be seen and identified easily at all times, except when they entered the burrow system in one part of the pit.

The interspecific behaviours demonstrated by the monitor group were recorded during July to September, 1990. Observations were limited to the daylight hours (0600 to 1930) as water monitors are typically diurnal (Gaulke, 1990) and unlikely to socially interact at any other time. Random checks confirmed that all of the monitors were asleep during darkness.

BEHAVIOURS WHICH ESTABLISH AND MAINTAIN THE DOMINANCE HIERARCHY.

Agonistic behaviours

These can be ranked on an arbitrary scale of aggression, from mild threats to overt attacks, entailing physical contact. These were invariably

directed by monitors only towards conspecifics of similar or inferior social status. Notable aggressive behaviours include the following:

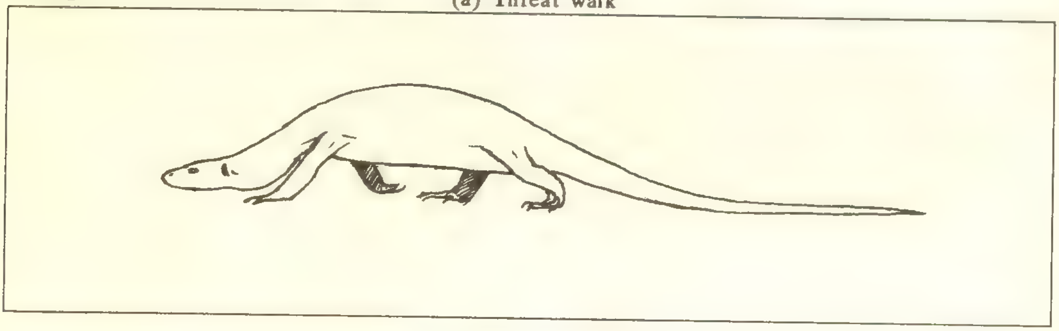
1) **Threat walk** (Fig. 1a). This is a relatively mild threat display. The aggressor ('A') performs a slow and stiff-legged walk, directly towards 'B' (the 'target' of the aggression). 'A's body is held abnormally high and laterally compressed. The vertebral column is arched and the head is held low on an outstretched, inflated neck. When performed by the dominant two year old male, this walk was commonly accompanied with lateral head jerks (i.e. the head was moved erratically from side to side. Auffenberg (1988) interprets this act as denoting dominance).

into the pond. 'A' then halts at the pond's edge. Alternatively, the short pursuit may be initiated in the water, and 'A' maintains the chase until 'B' climbs out onto the land.

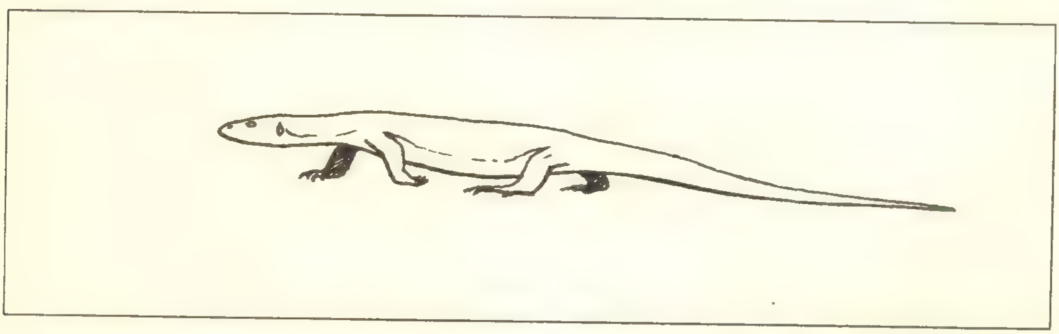
ii) **Long pursuit**. 'A' chases 'B' over a much greater distance. The monitors may enter and leave the water several times during the chase, and it is not unusual for several other high-ranking lizards to join in the pursuit of a common subordinate. Long pursuits end either when 'A' is apparently unable to locate 'B' any longer, or when 'A' succeeds in catching 'B'. 'B's capture may lead to the following agonistic behaviours:

FIG. 1

(a) Threat walk



(b)Normal walk



2) **Feigned Attack**. Further up the arbitrary scale of aggression, 'A' rapidly approaches 'B'- often from several metres away - over the land or through the water. 'A' then stops or veers away at the last moment.

3) **Persecution**

i) **Short pursuit**. If overland, 'A' runs towards 'B', and chases 'B' until the latter dives

4) **Straddling** (Fig. 2). 'A' attempts to pin 'B' down by mounting 'B'. 'A' may use its forelimbs to press 'B's forelegs to its side; thus hindering escape. 'A' will typically bite the nape of 'B's neck before releasing it.

5) **Shaking** (Fig. 3). This is perhaps the most aggressive behaviour to be associated with social status interactions. 'A', with a bite-hold on 'B'

FIG. 2 : Straddling

vigourously moves its head back and forth laterally. This commonly leads to serious injuries to the limbs and spine of 'B'. (At one time, 35% of the monitors were unable to walk normally as a direct result of being shaken. The forelimb of a two year old was almost completely severed after being shaken by a dominant lizard). Violent shaking is also an aspect of the saurian inertial feeding method (Loop, 1974), but the smaller monitor was always subsequently dropped and not consumed.

FIG. 3 : Shaking

Responses to aggression

The response shown by 'B' to aggression from 'A' varies according to the potential risk of injury and whether 'B' is prepared to challenge 'A's status. The possible responses may be classified as the following:

1) **Flight.** 'B' moves away from 'A'. Often, this is the 'ritual walk'; a slow, stiff-legged walk, with the neck greatly inflated (a stress reaction, according to Auffenberg, 1981a). The head is usually held high, and turned slightly so as to keep one eye fixed upon the aggressor whilst retreating. This behaviour may be equivalent to the 'ritual walk' described in the Komodo monitor, which is interpreted by Auffenberg (1981a) as signalling appeasement. But on many occasions, 'B' will run away rapidly, with or without its neck inflated. If the pond is nearby, 'B' will usually attempt to flee by swimming underwater. Fleeing monitors were never observed to escape from an aggressor by entering a burrow. (In contrast, small monitors would invariably enter the nearest burrow if approached by a human).

It should be noted that a lower-ranking lizard may demonstrate such avoidance behaviour even when the more dominant individual does not appear to be aggressive. The mere approach of the dominant one is frequently sufficient to cause the other monitor to flee. Monitors were noticeably more likely to show rapid flight from an ap-

proaching dominant lizard if the latter had recently been highly aggressive towards them.

2) **Warning displays**. These apparently signal to 'A' that 'B' is prepared to defend itself if 'A' persists in demonstrating offence. The most frequent type of warning display (29 examples seen) comprised the following acts (see fig. 4).

i) Neck inflation and arching.

ii) High stand (i.e. raising the body on all four extended limbs).

iii) Arch back (i.e. raising the back dorsally).

iv) Compress laterally (i.e. pulling together the sides of the trunk; in effect, increasing the dorsoventral distance).

v) Lateral orientation (i.e. orientating the longitudinal axis broadside to 'A').

'B' will consequently appear to be larger than normal, when seen from 'A's location. (This display was not accompanied with hissing, but otherwise appears to be identical to the warning display that the Madras Crocodile Bank's two large adult males would direct towards approaching humans).

An alternative warning display was twice performed by the subdominant male. This entails the body of 'B' being dorsally flattened and laterally tipped towards 'A' so that the maximum dorsal surface area could be seen by the other lizard. An identical warning display was observed in *Varanus gilleni* by Murphy and Mitchell (1974).

In both of these warning displays, 'B's head is turned to face 'A', and the mouth may be opened; presumably indicating that it is prepared to bite. A third warning display simply entailed 'B' raising its head and performing lateral head jerks towards the aggressor. Only the most dominant lizards (males and females) were seen to do this.

A bipedal warning display, as seen in several other varanids (e.g. *Varanus gouldii*: Barbour, 1943), was not observed in this group of *Varanus salvator*.

3. **Fighting.**

If 'A' does not retreat in response to 'B's warning display, and persists in an aggressive approach, 'B' will either resort to rapid flight (i.e. the warning display was bluff) or respond with reciprocal aggression. Fighting may take place on land or in the water. The monitors grasp each other with both forelimbs in a brachial embrace and frequently bite each other, especially on the head and neck. When fighting in water, the lizards commonly show the 'locked jaw' position (fig. 5) and may wrestle underwater for long periods - in one fight, neither combatant surfaced for air for over 12 minutes. Eventually, the weaker lizard releases its hold on the other.

Following a prolonged fight, the weaker lizard will usually lie with its body pressed against

FIG. 4 : Warning display

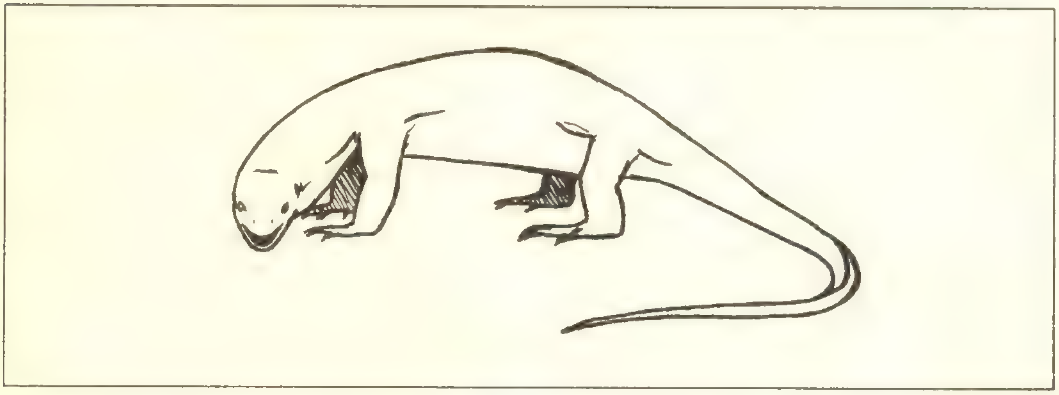


FIG. 5 : Locked jaw position

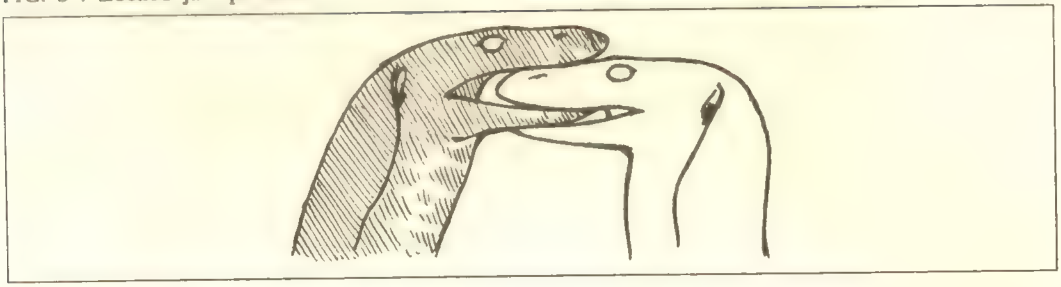
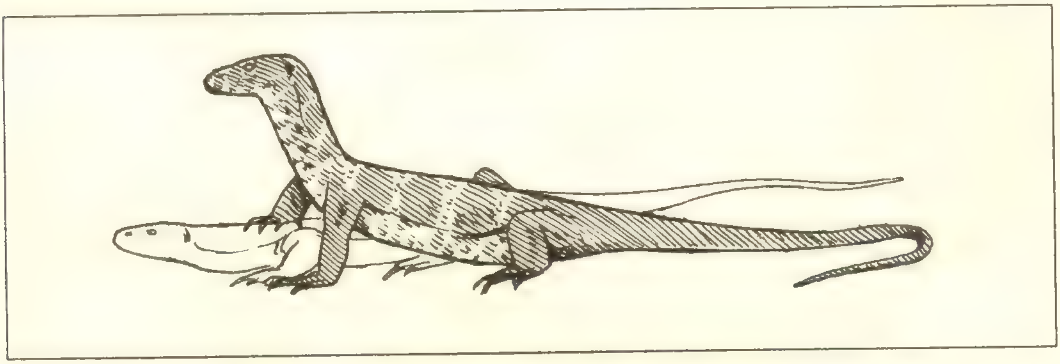


FIG. 6 : Subordinance



the ground for several minutes. Such body adpression may be a signal of subordinance (Auffenberg, 1988). The 'winning' monitor typically rests partly on top of it, (fig. 6) with one forefoot upon its back.

On three occasions, however, the fights for dominance developed into a form of combat which resembled the ritual combat of adult male varanids (e.g. described by Deraniyagala, 1958; Murphy and Mitchell, 1974; Davies et al, 1986). Whilst clasping each other in a venter to venter brachial embrace, the two combatants reared up on their hindlimbs (fig. 7a) and attempted to push one another over. No biting occurred, and the head of each lizard was held over the 'shoulder' of its opponent.

In all three cases, the larger monitor soon succeeded in forcing the smaller lizard to fall backwards. The latter turned over, so that the forefeet of the 'winner' were pressing upon its back. The dominant monitor performed lateral head jerks as it pushed the weaker individual to the ground (Fig. 7b). The two lizards then rested in the position shown in figure 6. It is to be noted that bipedal combat of this type has only previously been reported in adult males, but the combatants in these three fights were all two-year old females.

There does not appear to be a specific appeasement display which a water monitor can adopt in response to the aggression from a conspecific, but low ranking individuals may be able to adopt certain behaviours in order to avoid the risk of aggression occurring in the first place. Most attacks were initiated only when the lower ranking monitor was moving around - especially if it was on the ground - so it is conceivable that some of the monitors will deliberately rest motionless so as not to incite an attack. This may in part account for why the juvenile monitors (all low-ranking) spent 3 times as long resting motionless on branches, several feet above the ground, as the two year olds (as a percentage of total time spent out of the burrows).

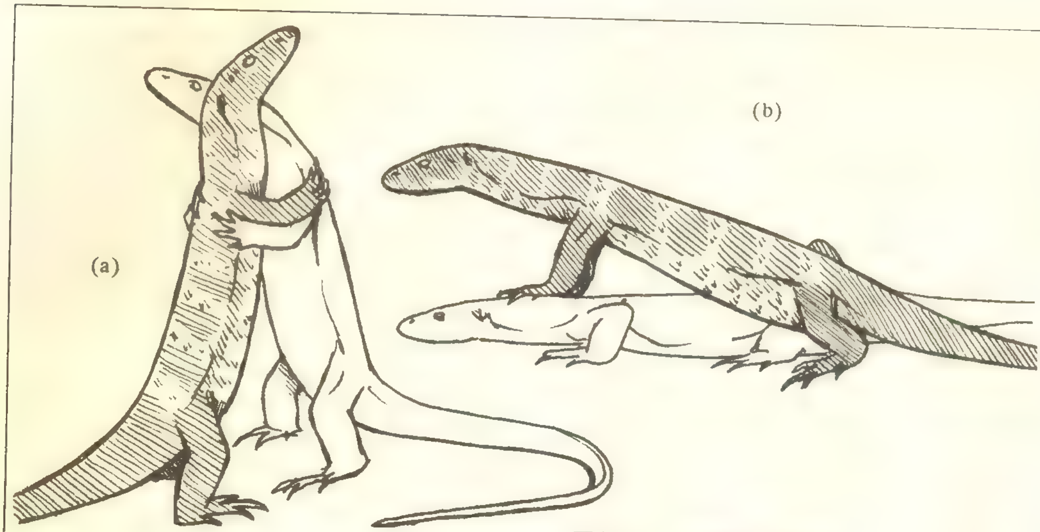


FIG. 7 : Bipedal combat

THE SOCIAL HIERARCHY WITHIN THE STUDY GROUP

By recording all of the demonstrations of aggression which occurred outside of feeding times (for reasons which will be explained shortly), and by examining the responses of the recipient of each threat or attack, it was possible to decipher the hierarchy within the study group. A monitor which invariably fled in response to aggression from (or even the mere approach of) another individual was deemed as being of lower social status. On the other hand, a monitor which rarely received aggression from another lizard - and could cause it to retreat after performing a warning display if it did behave agonistically - was considered to be dominant.

The hierarchy proved to be of a "peck-right" dominance type; that is, a rank series of dominance in which aggression was primarily directed by the higher ranking animals towards their subordinates, and not vice versa. Both genders of all age-classes were members of this hierarchy. Several lizards appeared to bear equal status and had dominants and subordinate conspecifics in common. Aggression from one monitor towards a conspecific of equal status invariably led to prolonged fights in which it was impossible to predict which individual would be the 'winner'.

The most dominant monitor in the group was the large adult male, 'C'. This individual rarely displayed aggression, but all of the other lizards would usually move out of his way (usually with a slow, stiff-legged walk, with the neck inflated) if he approached. All of the two year olds dominated over the juveniles. The lowest ranking monitors were two small juvenile females, 'r' and 's'. These routinely fled at the approach of all other monitors in the enclosure, including each other.

WHICH FACTORS DETERMINE A MONITOR'S SOCIAL STATUS?

1) Body size

The monitors were ranked in order of SVL (the most reliable measure of body size; body weights tend to fluctuate greatly as the monitors typically eat large and infrequent meals). Relative body size and social rank were highly significantly correlated ($N = 17$; $r_s = 0.952$; $P < 0.0005$); larger lizards tended to be higher ranking. This relationship is unsurprising, because the larger individuals must have the considerable advantage of weight and strength when fighting with conspecifics.

2) Gender

This factor appears to have little importance in determining a lizard's status. While it is true

that males tended to be of higher status (x rank = 7.8 ± 5.8 [N = 6] ; x rank = 9.6 ± 4.7 [N = 11]), this may be attributable to the fact that the males in this group tended to be larger than sibling females (table). The two year old females 'i' and 'l' were intermediate in size to the males 'd' and 'e', and similarly intermediate in rank.

3) **Aggressiveness**

Perhaps a monitor can gain status by being relatively more aggressive. (Testosterone implants in Harris' sparrows has been shown to result in those birds becoming more aggressive and consequently gaining higher social status: Rohwer and Rohwer, 1978). The monitors were ranked in order of 'aggressiveness' (according to the number of threat walks, feigned attacks, pursuits, straddling and shakings that each lizard had initiated (table). Social status is positively correlated with aggressiveness (N = 17; rs = 0.638; P <0.005). More agonism was initiated by two year olds (mean percentage of threats and attacks = 9.99 ± 9.89) than by the lower ranking juveniles (mean = 0.097 ± 0.236%). Within the two year old group, the higher rankers were more aggressive than the lower rankers; mean percentage of aggression initiated by 'd', 'i', 'f', 'l' and 'e' = 16.14 ± 10.00; mean percentage initiated by 'k', 'h', 'm', 'g' and 'j' = 3.84 ± 4.60.

Perhaps female 'f' is higher ranking than 'h' would be predicted on the basis of body size alone because this individual is relatively aggressive. ('f' is the same size as 'h' but initiated more than twice as many attacks, and is of higher rank).

It is difficult to determine the cause-effect relationship between rank and aggressiveness. Could increased aggressiveness be a function of higher rank? However, in July 1991 a gravid female ('q' SVL = 47.5 cm) in the original study group became unusually agonistic towards all of the other monitors for a few days, concurrent with digging trial nest chambers. Initially, the dominant male ('d'. SVL = 63.0 cm) would respond to her attacks with reciprocal aggression, and clearly 'won' each fight. But eventually even this male would retreat, with neck inflated, whenever this female directed lateral head jerks or a threat walk towards him - indicating that this

TABLE : % Aggression initiated: This is the percentage of threats or attacks that each monitor initiated during 95 hours of observation between 8.7.91 and 6.8.91.

MON.	SEX	AGE	SVL	ROS	%AI	ROA	ROD
'c'	M	10+	120.0	1.0	0.00	14.0	1.0
'd'	M	2	53.5	2.0	26.74	1.0	2.0
'e'	M	2	48.0	5.0	1.63	8.0	5.5
'f'	F	2	45.0	8.5	12.79	4.0	5.5
'g'	F	2	48.0	5.0	1.74	7.0	9.0
'h'	F	2	45.0	8.5	5.81	6.0	7.0
'i'	F	2	49.0	3.0	13.95	3.0	3.5
'j'	F	2	42.0	11.0	0.00	14.0	11.0
'k'	F	2	42.0	10.0	10.47	5.0	9.0
'l'	F	2	48.0	5.0	25.58	2.0	3.5
'm'	F	2	47.0	7.0	1.16	9.0	9.0
'n'	M	1	39.0	12.0	0.00	14.0	11.0
'o'	M	1	38.4	13.0	0.00	14.0	12.0
'p'	M	1	36.0	15.0	0.58	10.0	13.5
'q'	F	1	37.0	14.0	0.00	14.0	5.0
'r'	F	1	32.7	16.0	0.00	14.0	16.5
's'	F	1	31.0	17.0	0.00	14.0	16.5

Mon. = Monitor, SVL = Snout-vent Length (cm), ROS = Rank order of size (1 = biggest), %AI = Aggression initiated, ROA = Rank order of aggression (1 = most agressive), ROD = Rank order of dominance

Snout-vent length : Most monitors were measured in July 1990. SVL of three monitors were estimates based upon comparison with the monitors of known length.

relatively small female had gained a temporary dominance through her increased aggressiveness.

A notable exception to the correlation between social rank and aggressiveness is the most dominant member of the hierarchy. 'c' was rarely observed to be aggressive. This animal's considerable size may alone have been sufficient to intimidate the other monitors into subordinance.

THE EFFECT OF THE FEEDING REGIME UPON AGGRESSION

The frequency with which monitors in the enclosure would encounter one another was very high, partly because they were housed at a high density (0.17 lizards/square metre) and partly because this species is naturally active (e.g. between 1100 and 1830, the two year olds spent a mean of 8.7% of their time walking, swimming, feeding, digging or climbing). The number of these interactions which were aggressive differed from day to day, even when comparing observations made during the same times of the day. Prior to 8/7/90, and after 6/8/90, the monitors were fed almost daily with rats, frogs, fish or mole-crabs, and interspecific aggression was rarely observed. Between those dates, however, food was provided less frequently and less was available at each feeding session. As can be seen in the following graph, there was an increase in frequency of agonistic interactions with time after the last feeding session.

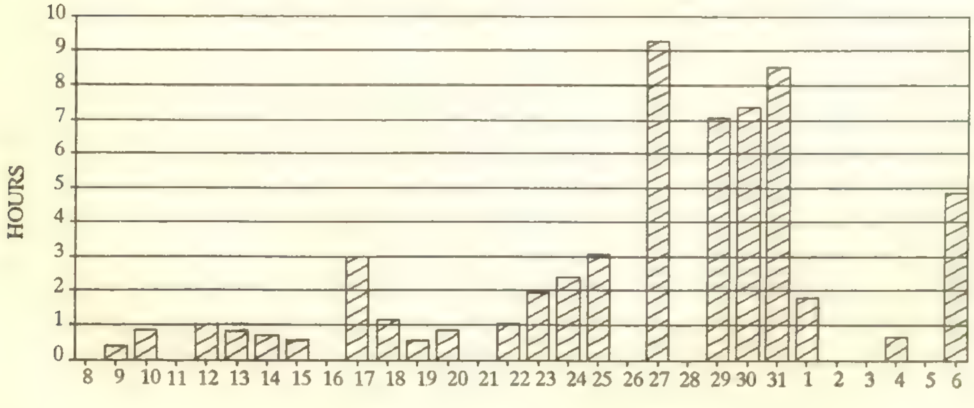
Note the exceptionally high numbers of attacks occurring from 27/7 to 31/7/90 (by which time the monitors had not eaten for at least 8 to 12 days). Subsequent to feeding on 1/8 and 2/8/90 (all monitors were seen to consume at least one rat each), the frequency of aggression plummeted for a few days, despite no significant change in either the number of monitors active above ground or the climate.

In addition to the number of aggressive interactions, the severity of the aggression similarly appeared to be influenced by how recently the monitors had been fed. There was a disproportionate increase in the frequency of highly aggressive acts, such as biting and shaking, with time after the last feed. This resulted in many serious injuries, especially to the smallest, lowest ranking individuals.

However, the attacks were clearly not cannibalistic, and the subordinate monitors were always released alive after receiving the injury.

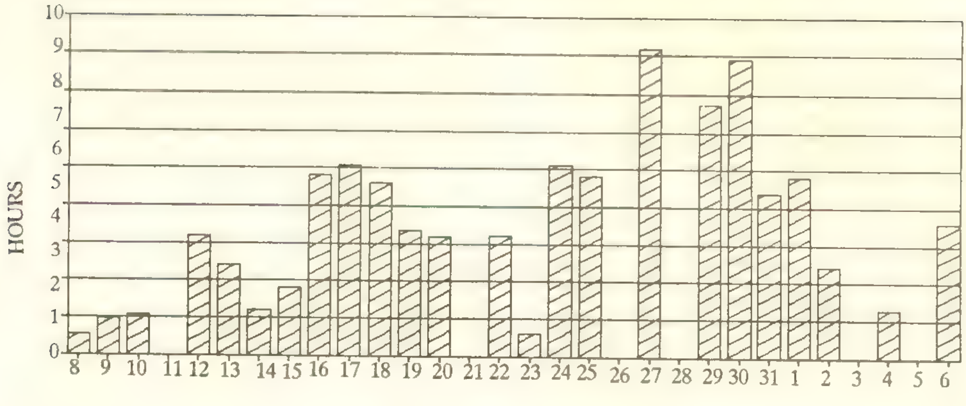
Water monitors are not normally territorial (Gaulke, 1990), but it would appear that food shortages cause the highest ranking individuals to attempt to drive away potential competitors for food from the vicinity. The lower ranking lizards in this enclosure were persecuted relentlessly during 'fasts', and showed an increased readiness to flee even when dominant lizards appeared to be approaching passively. Figure 9 shows the daily

FIG. 8 : Mean number of threats and attacks per hour*



8th July to 6th August, 1990

FIG. 9 : Mean number of ritual walks per hour*



* Daily mean number per hour extrapolated from at least 3, and usually 5 hours of observations per day. Observations made each day during late morning and late afternoon (the peak activity periods).

mean frequency with which monitors were clearly seen to show the ritual walk (described on page 6) or ran away from an apparently passive dominant lizard.

THE IRRELEVANCE OF THE HIERARCHY DURING FEEDING SESSIONS

When food is provided, all monitors attack each other to gain possession of the food, and vigourously defend prey items. A monitor approaching a second with food will usually run towards it, to approximately one metre away, and then continue its approach more slowly (having come within range of a defensive tail-slap). To 'steal' food, the monitor will either attempt to bite the feeding lizard's head or move alongside it and lash it with the tail, notably striking the feeding monitor around the head. These actions may succeed in forcing the other lizard to drop the prey item. The feeding lizard will often attempt to run away with its prey, or hiss loudly and lash any nearby conspecifics with its tail.

Such attacks and defensive behaviour associated with a food item may be directed at conspecifics regardless of their relative social status. Even the smallest juvenile, 's', was seen to tail-slap the head of the large dominant monitor, 'c', in an attempt to gain possession of a rat. Note that tail lashing and hissing are important components of interactions between monitors in situations where one of the coactors has a prey item, but were rarely observed in normal social status interactions.

The apparent irrelevance of each water monitor's social rank during feeding sessions contrasts with Auffenberg's (1981a) observations of aggregations of Komodo monitors around a carcass. In the latter species, the monitors space themselves around carrion in a pattern related to their social status.

DISCUSSION

The organisation of a group of water monitors into a dominance hierarchy is unlikely to be a mere artifact of captivity. In the wild state, an individual may share some or all of its home range with a number of conspecifics, and field studies on other species of varanids have revealed that the wild lizards are organised into a hierarchy in a similar manner to their captive counterparts (e.g. *Varanus komodoensis* : Auffenberg, 1981a)

Carpenter (1967) states that "the development of hierarchies is dependent upon individual recognition". By this, he presumably means that

a varanid needs to somehow be able to identify a particular individual in order to behave appropriately towards it, according to whether it has proved to be its social superior or inferior in the past. The ability to specifically recognise other individuals of the same species is perhaps not normally expected of reptiles. Rand (1967), however, believes that the iguanid lizard *Anolis lineatropis*, appears to show this as a behaviour pattern. Auffenberg (1981a) is convinced that varanids also have this ability, and probably recognise other members of the local hierarchy from their unique body surface olfacients. (He even suggests that a monitor can relate faecal odour to the particular lizard which produced the scat; a Komodo monitor encountering the faeces of a more dominant conspecific will often perform behaviours associated with subordinance).

Several features of varanid biology would appear to favour the development of individual recognition. Firstly, varanids tend to remain within a home range and, as varanids are long lived (Auffenberg, 1986, suggests a lifespan of 25 years), each lizard may be interacting with the same conspecifics for a number of years. Secondly, relative to other reptiles, varanids appear to have an exceptionally high level of intelligence (Pianka, 1982).

Observations of the captive study group of water monitors strongly indicated that the monitors could recognise at least some of the other hierarchy members. For example, walking lizards would often give wide berth to an individual which had recently attacked them, even when the latter was merely basking. The walking lizard would also commonly show neck inflation (a stress reaction, according to Auffenberg, 1978) as they veered around the dominant monitor. In agonistic interactions, dominant lizards frequently rushed towards their target subordinate from several metres away - whether recognition is based upon sight, scent or both was not clear.

But perhaps individual identification is not always necessary in social status interactions. It could be argued that a varanid may be able to rely upon mere "clues" as to another lizard's status in order to behave appropriately towards it. It is conceivable that a lizard can make use of the good correlation between body size and social rank and respond to any smaller lizard with dominance behaviours.

The key advantages to the highest ranking members of the local hierarchy are likely to be the ability to displace other monitors from basking and resting sites, and receiving a disproportionately low number of attacks from conspecifics. The highest ranking males may also be more successful in courting females; it should be possible to record if this is true when more of the study group mature.

When food is scarce, the dominant animals can reduce local competition for prey by becoming more aggressive towards the lower ranking lizards in order to drive the latter away from the vicinity. When food is plentiful, however, the benefits to be gained from expelling conspecifics from the home range may not exceed the costs of energy expenditure and risk of injury in performing the aggression. High densities of water monitors may then coexist relatively peacefully.

Dominance rank appears to be almost entirely a function of body size; the largest lizards have the greatest advantage in fights to establish status. The presumably greater survival and reproductive success of the more dominant individuals relative to their subordinates may create a powerful selective force for greater body size in this species. Perhaps this partly accounts for why the water monitor is one of the largest species of lizard. (Maximum total body length of 2.7 metres: Bennett, 1989).

Implications for captive management.

Aggression among monitors in social status interactions results in high levels of stress and injury, especially to the smallest, lowest ranking individuals. This surely leads to these animals having their thermoregulatory behaviour seriously disrupted, and showing a poorer weight increase. One of the study group juveniles eventually died as a result of the damage it had received in numerous 'social status' attacks.

Aggression can be minimised by reducing the stocking density and by keeping animals of greatly differing body size in separate enclosures. Enclosures should have ample vegetation, rocks and mounds in order to screen monitors from one another's view. A large body of water provides a useful escape route for individuals receiving aggression. It is also advisable to ensure that the monitors are fed as frequently as possible in order to reduce aggressiveness - provided that they do not become obese.

ACKNOWLEDGEMENTS

I wish to thank the Madras Crocodile Bank - and in particular the Deputy Director, Harry Andrews - for making it both possible and a pleasure to carry out this study.

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MORPHOMETRICS OF *ERYX CONICUS* (Schneider) AT A LOCALITY IN SOUTH INDIA (SQUAMATA : BOIDAE)

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ABSTRACT: This paper deals with the length-weight relationships of Russell's sand boa: that body length bears a strong positive correlation with tail length, head width and body weight. Sand boas are sexually dimosphic and the sex ratio of this sample was 1:1.

INTRODUCTION

While data on size and scutellation of many common Indian snakes are available, length-weight relationships, which are useful for describing surface area-to-volume ratios and the subsequent effect it has on metabolism (see Kaufman and Gibbons, 1975) have been largely ignored, due no doubt to the fact that most of the work on descriptive morphology concerning these organisms have been based on long-preserved material. In addition, while describing patterns of scutellation, few workers have had access to large samples collected from a single locality, most works based on material from widely scattered areas, and hence data on variability in scutellation in the population of a specific locality, even for the most common snake species are unavailable.

This study is focussed on *Eryx conicus*, the Russell's sand boa, or common earth boa, widespread in the comparatively xeric regions in the Indian subcontinent. The biology of the species has been summarized by Whitaker (1978). A specialized burrowing erycine, the species utilises short burrows, especially in slightly sloping terrain, from where it ambushes passing invertebrate and occasionally small vertebrate prey. Large beetles were found to be the main diet of the population under investigation (Das, unpublished obs.).

METHODS

Twenty one examples of *Eryx conicus* were collected between February and May, 1990, from Chengai Anna (formerly Chingleput) District, Tamil Nadu State, in south India. Specimens were mostly dug up from in and around paddyfields and scrubland along a stretch of coastal land. Total body length (TBL) was taken to nearest 0.5 cm with a steel tape; head width (HW) and tail length (TL) to nearest 0.01 cm with a dial vernier caliper. Counts of the following scales typically utilized in characterising the

TABLE 1 : Morphometric data on Eryx conicus (sex-wise and pooled). References: TBL, total body length; TL, tail length; HW, head width; Wt. weight. Length in cm; weight in gm. individuals examined had large quantities of visceral fat, but none of the adults had oviducal eggs, embryos or showed pronounced testicular development.

	N	TBL range (X ± SE)	TL range (X ± SE)	HW range (X ± SE)	Wt range (X ± SE)
Males	10	22.1 - 67.1 (42.58 ± 3.82)	1.37 - 4.73 (3.07 ± 0.28)	0.76 - 2.37 (1.43 ± 0.14)	9.9 - 290.0 (92.4 ± 25.1)
Females	11	33.2 - 62.0 (46.1 ± 2.82)	2.12 - 3.89 (3.03 ± 0.20)	1.09 - 2.25 (1.525 ± 0.96)	31.7 - 280.0 (112.1 ± 23.3)
Pooled	21	22.1 - 67.1 (44.42 ± 2.31)	1.37 - 4.73 (3.02 ± 0.16)	0.76 - 2.37 (1.48 ± 0.08)	9.9 - 290.0 (102.7 ± 16.8)

TABLE 2 : Body proportions in Eryx conicus. References: TL/TBL, tail length/ total body length ratio; HW/TBL, head width/total body length ratio, sex-wise and pooled.

	N	TL/TBL range (x ± SE)	HW/TBL range (x ±SE)
Males	10	0.062-0.0789 (0.0703 ± 0.0017)	0.0274-0.0363 (0.0339 ± 0.0009)
Females	11	0.0606-0.0746 (0.0656 ± 0.0015)	0.0241-0.0363 (0.0333 ± 0.0001)
Pooled	21	0.0606-0.0789 (0.0679 ± 0.0012)	0.0241-0.0363 (0.0356 ± 0.0007)

species, ventral (V), midbody (M), subcaudal (S), upper and lower labials (UL and LL, respectively) on the left side of the jaws, scales between the eyes (SBE) and scales around the left eyes (SAE), were made. The weight (Wt) of all samples were taken: snakes less than 200 gm were weighed to nearest 0.10 gm with an Acculab Electronic Digital Scale (Model 333), while heavier individuals were weighed to the nearest gm with a Pesola Balance.

The sample of twenty one snakes comprise eleven female and ten males, indicating that the male: female ratio is not significantly different from 1:1. The under representation of juveniles in the sample is thought to be because of their comparatively more cryptic habits and small size. Juveniles of TBL 20-30 cm TBL comprised one of 21 (or 4.76%) of the sample, while five (23.81 %) and nine (42.86%) individuals belonged to the 30-40 and 40-50 cm size-classes, respectively.

TABLE 3 : Statistics on scutellation in Eryx conicus (sex-wise and pooled). Abbreviations: V, ventrals; M, midbody;

	N	V range (X ± SE)	S range (X ± SE)	M range (X ± SE)	UL range (X ± SE)	LL range (X ± SE)	SBE range (X ± SE)	SAE range (X ± SE)
Males	10	167-178 (173.5 ± 1.13)	17-20 (18.9 ± 0.31)	44-47 (45.2 ± 0.33)	11-14 (12.8 ± 0.25)	15-20 (17.8 ± 0.44)	7-9 (8.2 ± 0.20)	11-14 (11.8 ± 0.25)
Females	11	170-181 (175.0 ± 1.13)	16-21 (18.2 ± 0.42)	42-48 (45.45 ± 0.61)	13-13 (13 ± 0.00)	16-20 (17.54 ± 0.39)	8-9 (8.09 ± 0.09)	10-13 (11.54 ± 0.25)
Pooled	21	167-181 (174.29 ± 0.8)	16-21 (18.52 ± 0.27)	42-48 (45.33 ± 0.35)	11-14 (12.91 ± 0.12)	15-20 (17.67 ± 0.29)	7-9 (8.14 ± 0.1)	10-13 (11.67 ± 0.17)

RESULTS

The typical colouration (terminology after Smithe, 1975) of individuals of *Eryx conicus* in the population under investigation comprises a brownish-olive forehead and dorsal body, with raw umber blotches that are sometimes edged with a yellow ocher or cream, ventrally cream. Sclera chamois, and there is a raw umber postocular streak. Individuals belonging to the smaller size-classes are, as a rule, brighter than older ones.

Most individuals examined had large quantities of visceral fat, but none of the adults had oviducal eggs, embryos or showed pronounced testicular development.

Besides possessing larger hook-like claws around the cloaca, males have a slightly but significantly larger tail, compared to females (t-test, $t = 2.74$, $p < 0.05$; data in Table 2). Although the largest and heaviest specimen examined was a male, males are not significantly larger (t-test, $t = 1.25$, $p > 0.05$) or heavier (t-test, $t = 0.85$,

Relationship between TBL and TL on a log-log scale

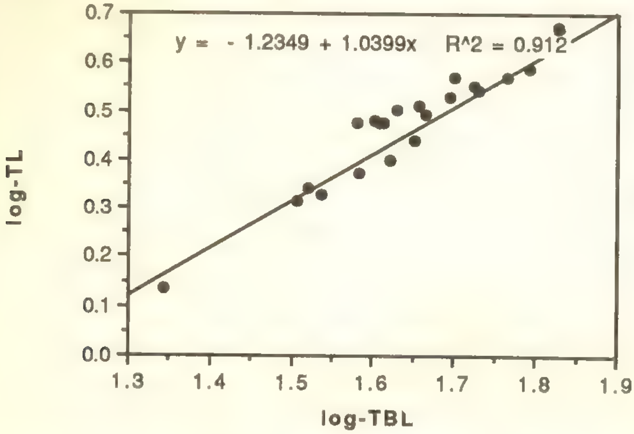


FIG. 2.

Relationship between TBL and HW on a log-log scale

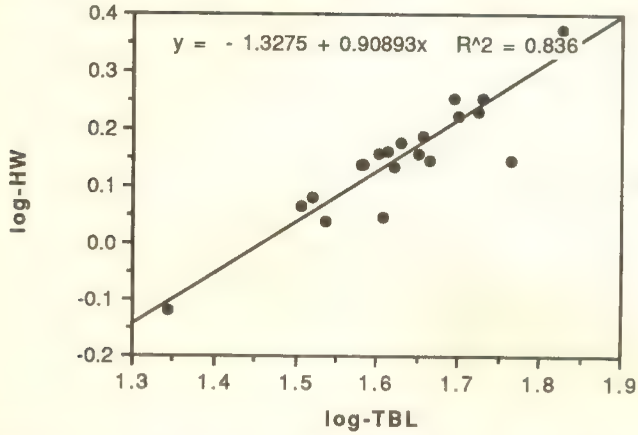


FIG. 3.

Relationship between TBL and Wt, on a log-log scale

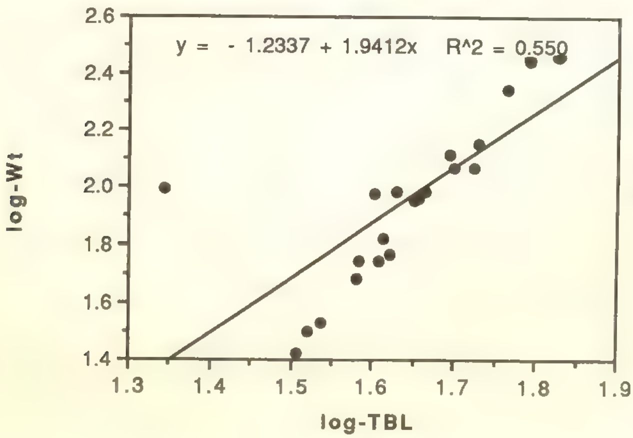


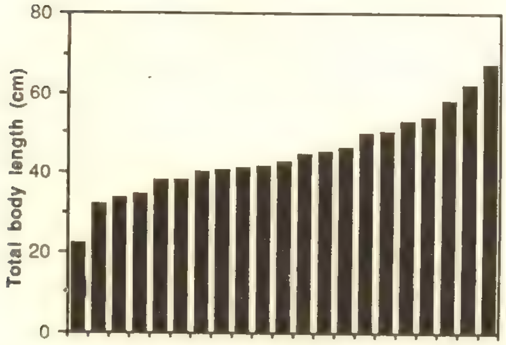
FIG. 4.

TABLE 4 : Data on regression of total body length (TBL) to head width (HW), tail length (TL) and body weight (Wt), on a log-log scale.

	slope (a)	intercept (b)	coef. corr. (r^2)
HW to TBL	-1.3275	0.90893	0.836
TL to TBL	-1.2349	1.0399	0.912
Wt to TBL	-1.2337	1.9412	0.550

$p > 0.05$; data in Table 1) than females, mean TBL and Wt of females being 46.10 ± SE 2.82 cm and 112.1 ± SE 23.3 gm, respectively. However, females are, on average, both larger and heavier than males, mean TBL 42.58 ± SE 3.82 cm and mean WT 92.3 ± SE 25.1 cm, respectively.

FIG. 1: Distribution of total body length (TBL, cm) in Eryx Conicus showing the size-classes.



Figures 2 and 3 show the relationships between TL and HW to TBL, on log-log paper (see Gould, 1966, for justification). Both relationships can be described as linear and significant ($p < 0.05$) and positive ($r = 0.95$ and 0.91, see also data in Table 4). The relationship between Wt and TBL (Fig. 3) is less tightly constrained ($r = 0.74$), perhaps due to the varying levels of visceral fat bodies.

DISCUSSION

The study reveals that body length bears a strong positive relationship with tail length, head width, and slightly less so with body weight. In addition, the population is sexually dimorphic, males possessing proportionately longer tails, with larger hooks near the cloaca, but are not longer or heavier than females. Sex ratio is close to 1:1. Variability in counts of the major scales was found to be considerable.

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STUDIES OF PAKISTAN REPTILES NOTES ON *KACHUGA SMITHI*

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ABSTRACT : Reproduction and feeding of Kachuga smithi (mainly adult females) was analyzed at a site in Punjab, Pakistan. Mature females lay 1 to 2 clutches of 7-9 eggs per year, most vitellogenesis occurring during August and September and most eggs being laid in September. Eggs measured 39.2 - 42.4 mm x 22.3 - 26.5 mm. Aquatic herbs comprised almost all of the food in the stomachs and the heaviest feeding occurs during May and August. In this area individuals are torpid from November through February.

INTRODUCTION

The following account reports the results of a study conducted on the Brown Roofed Turtle, *Kachuga* (Pangshura) *smithi smithi*, primarily reproductive and feeding biology. The species is indigenous to the middle and lower reaches of the Indus River in Pakistan and to the upper and middle sections of the Ganges River in India, as well as all of their major tributaries. It also occurs in the Brahmaputra system in Bangladesh. In Pakistan the species ranges from the frontal mountains of the Himalayan mountain complex south to the Sindh Coast. Within this area it occurs in a wide variety of aquatic situations, from fast flowing major rivers to slow moving or even still backwaters and connecting canals. It is usually most abundant in shallows choked with grasses and/or weeds, where large numbers can sometimes be seen basking together on exposed logs and rocks.

Though some wide-ranging freshwater turtles occurring in the subcontinent have been studied in India (see Moll 1986, 1987 for latest review), relatively little information other than distribution records is available for populations of these same species in India. However, for *Kachuga smithi* even data for the Indian populations are relatively scarce. This is because it is not a common species outside of Pakistan (India: Smith 1931 and Moll 1987; Bangladesh: Khan 1982), where within the last several decades it has apparently been considerably reduced in numbers (for food and because of habitat destruction, Tikadar and Sharma 1985). It is because few data have been published on the species and because it is considered rare in at least the central and eastern parts of its range that the current study was undertaken.

Smith (1931), Minton (1966), Das (1985), and Moll (1987) have reported on the feeding habits of the species. Reproductive data are provided by Chaudhuri (1912) and Minton (1966).

MATERIAL AND METHODS

The study area is located in Pakistan, Punjab Province, Muzzafargarh District, near Taunsa Barrage, at DGK Canal (70°75′ E, 30°50′ N.). The site is a section of a silt discharge and distribution canal in which water depth is a maximum of 6 m, though mostly is about 0.5 m; width is about 80 m. Water flow rate is rapid, particularly at the discharge sluice next to the DGK Canal. Most of the turtles examined were taken while they were basking on rocks at the edge of the discharge pool near the sluice, which contained the deepest water. The surrounding banks were low and silty. The most common emergent plant is *Typha* (cf. *angustifolia*) and the most common submerged one is *Nostratum officianalis*. In some areas the grasses *Muncus articuta* and *Imperata cylindrica* also occur in dense stands.

The study is based on a total of 78 mature females. Once each month from May, 1990, through April, 1991, a series was collected. Each turtle in the series was killed, immediately preserved and stored for later study at the Multan Laboratory of the Zoological Survey Department.

CL was determined in the standard straight-line measurement from the most anterior part of the nuchal scale to the most posterior part of the supracaudal scale. Measurements (and abbreviations) used are carapace length (CL) in mm, volume of one ovary (VOL) in ml, diameter of the three largest follicles in the ovary (DIA) in mm, total number of eggs in both the right and left oviduct, maximum length and width diameters in mm of each of the shelled eggs. For both sexes only the food in the stomach was removed, the total volume being determined (in ml) and identified to species wherever possible.

RESULTS

Sex Ratio : Males were remarkably few in this population, representing only 7.7 percent of the individuals taken, producing a female-biased sex ratio 1:10.7.

Maturity and Size : On the basis of development of mature follicles, females become sexually mature at CL 125 mm. On the basis of developed testes, males are mature at CL 95 mm.

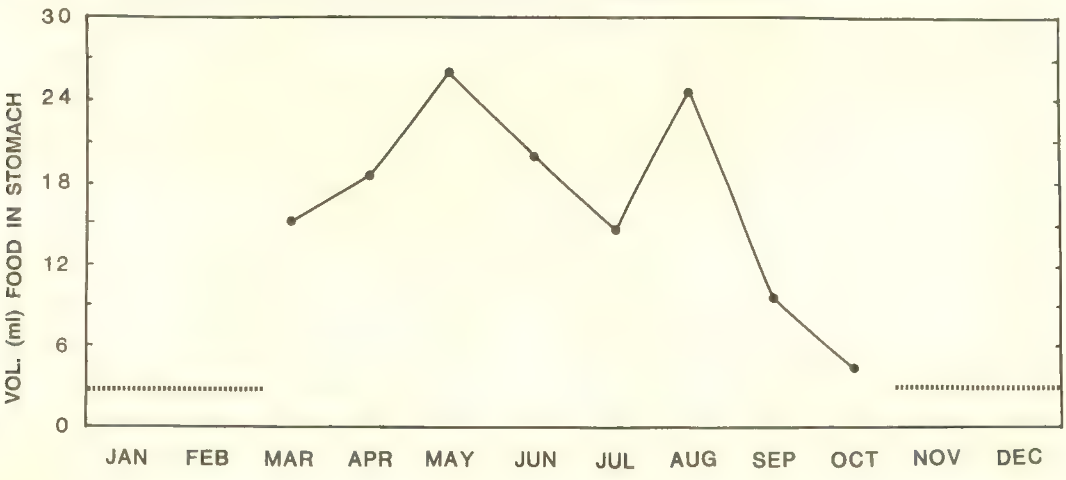
Activity : Individuals were found to be active at this site every month inclusively from March through October.

Food : Nine different food taxa are recorded. Only three individuals (3.8%) contained any traces of animal food in the stomach, in each case a single leech (unidentified). The vast bulk of the food in all stomachs was plant material, representing eight species. There was no demonstrable difference in the food preference of mature males and females. No juveniles were collected. The stomachs of seven individuals (8.1%) were empty.

TABLE : Frequency and representation of nine plant taxa in the stomachs of a series of 92 Kachuga smithi smithi

Food Type	No. Turtles	Percent of Total
Typha angustifolia	23	25.0
Nostratum officinalis	15	16.3
Desmochachyes bipinata	20	21.6
Cyperus nitidis	19	20.5
Saccharum muni	6	6.5
Cynodon dactylon	3	3.3
Potamogeton sp.	4	4.0
Polygonum sp.	1	1.4
Amaranthus viridis	1	1.4

FIG. 1 : Seasonal variation in volume of food in the stomach of adult Kachuga smithi.



The plant species recorded as food are all seed-bearing types. Most are monocots, consisting largely of grasses, or grass-like plants, i.e. *Typha angustifolia*, *Saccharum munj*, *Cynondon dactylon*, *Desmocachyes bipinata*, *Cyperus nitidis*; a few are dicots, i.e. *Pota mogeton* sp., *Nostratum officinalis* and *Amaranthus viridis.*

No attempt was made to quantify the amount of each plant species eaten, but the distribution shown in the Table is instructive. Of the plants eaten, those that are found in 20 percent or more of all the individuals examined are *Typha*, *Nostratum*, *Cyperus*, and *Desmocachyes*. The remaining species are considered accidental (see below).

The average volume of food in the stomach was 16.9 ml. Figure 1 shows that the stomach contains the greatest amount of food in May, and the least during October (when these turtles are still active, but just before they begin their cool season torpor). There is more food/stomach each month after activity begins in March until the annual peak is reached in May. During June and July significantly less food is eaten. A secondary peak occurs during August, after which successively less food is found in the stomach until winter inactivity begins.

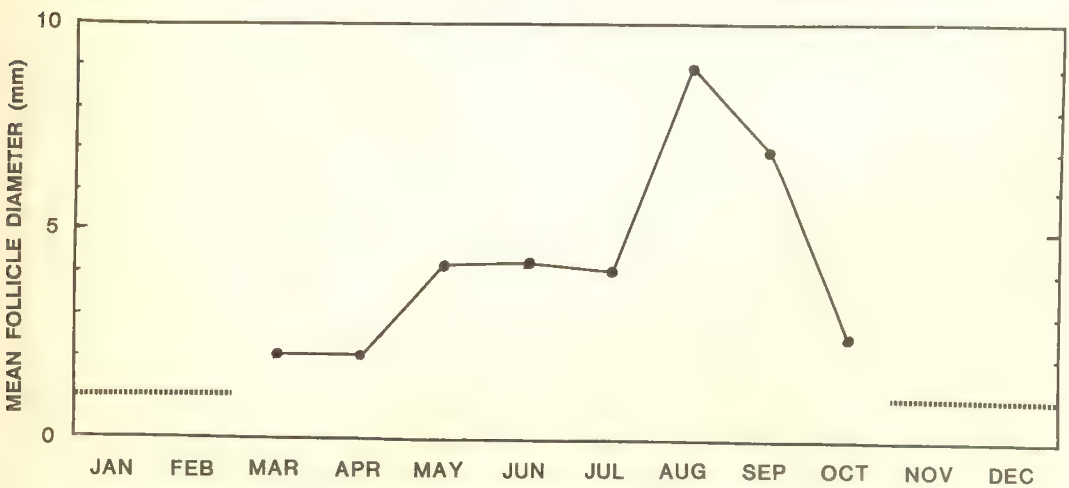
Reproduction : The reproductive cycle for females was determined by three standard methods: the volume of one ovary, the size of the three largest follicles, and the presence or absence of shelled/unshelled eggs in the oviduct.

Figure 2 shows the seasonal change in mean ovary size in mature individuals. During August and September the follicles are accumulating yolk; ovulation and shell formation also occurs during these months, for oviducal shelled eggs were found during September.

The number of eggs found in the oviducts varied from 7 to 9, with the number in the right and left member being nearly equal (e.g., 4/3, 4/5). It appears that at least two egg clutches are laid each year. This is based on the fact that in two females possessing shelled oviducal eggs, and which were ready to be laid, very large yolked ova (21.7 - 25.9 mm diameter) were present in the ovaries at the same time. Their size (nearly that of the shelled egg least diameters) suggests that ovulation would have occurred shortly—probably within a few days.

The eggs are oval, the long diameters varying from 40.0 to 42.4mm (X 40.9, SD 0.7) in one female and 39.2 to 41.5 mm (X 40.6, SD 0-.8) in the other. Least diameters vary from 22.3 to 24.7 mm (X 23.6, SD 1.8) in one clutch and 22.3 to 26.5 (X 24.8, SD 1.5) in the other. Overall means are greatest diameter 40.8 and least diameter 24.1.

FIG. 2. : Seasonal pattern of mean diameter of largest ovarian foll licles in adult Kachuga smithi.



A newly hatched individual collected from the weed-choked shallows of the Indus (in connection with another study) had a CL of 35.8 mm – within the range listed by Ewert (1979) for the four Indian specimens at his disposal.

DISCUSSION

Our results of the food analysis is at variance with information provided by Smith (1931), Minton (1966) and Das (1985). These workers concluded that, while the species is omnivorous, flesh is the preferred food; Minton reports insects were commonly taken. None of these studies apparently included stomach content analyses, and we assume their conclusions were based entirely on the behaviour of captives. Our material is based on 1) a large sample, 2) wild-caught animals. The fact that plants predominate in a very significant manner among the foods taken raised the question of what plant foods might have been offered the captives and whether they were something the turtles would be expected to be familiar with. Minton mentions fruit as being taken, but this would be rarely obtainable by wild individuals. Of these workers, Moll reports only plant material in the gut. This conclusion is based on the examination of a single wild Indian specimen. As a result of the present study we conclude that adult *Kachuga smithi* are largely herbivorous, rather than largely carnivorous as stated previously. Our sample of adult males is small so our conclusion of a similar largely herbivorous diet is more tentative and needs confirmation. However, we do expect that juveniles will be found to be largely carnivorous in view of the general need of young turtles to subsist on a highly proteinaceous diet during the early growing years. But this remains to be demonstrated.

Of the plants eaten, the vast majority are species that are unquestionably aquatic (*Typha*, *Nostratum*, *Potamogeton*) but some live either on the marshy edge of streams,or even on dry land (*Amaranthus*, *Saccharum munj*, etc.). Plants in the two last categories (edge and dry land species) were found in small quantity in the guts we examined. We do not believe that the turtles left the water to feed on them, as there is no evidence that individuals of any species of *Kachuga* do so. We conclude that these plants are accidental food types, occurring in the gut because a few leaves hung into or over the water. Thus the major food of adults in this population is *Typha angustifolia*. *Nostratum officianlis*, and *Desmocachyes bipinata*.

Our data on the amount of food eaten seasonally suggests that feeding is most intense during June. Since the water level remains more or less constant in this site throughout the year, we presume that this peak is related to building fat reserves needed for vitellogenesis, which from our reproductive data is shown to occur during July and August in this population.

Curiously, there is a diminution of food in the stomach during July. We presume this is due to reduced attention to feeding during this major courtship and breeding month.

Our data on the number and size of eggs is consistent with those obtained for the species in other parts of its range, except that we report a higher mean and maximum of 9 rather than 8 eggs per clutch. The mean number of eggs per clutch (total of all data available from all sources, N = 80) is 6.7. Calculation of female reproductive effort (as relative clutch mass) on the basis of the material available in this study results in a mean RCM value of 0.16 (less than 0.21 as reported for the close relative *Kachuga tecta*, and more than the 0.08 reported for *Kachuga tentoria circumdata* (both by Moll 1987). These are the only other published data available for congenerics.

Both of our gravid females ready to lay eggs were collected in September. In his important study of Pakistan reptiles, Minton (1966) reports only a single clutch, laid in October. This data was based on the behaviour of a captive from southern Sindh, where this species can be expected to be reproductively active over a longer period of time than in Punjab where cool winter weather arrives earlier in the year. We believe that while the first of the apparently two annual egg clutches probably hatches later during the same year they were laid, the second clutch does not have sufficient time to develop before cool winter weather. Thus we presume that this

second clutch remains dormant during the winter months, hatching during spring of the following year. Apparently over-wintering of eggs is a common reproductive pattern in Indian species of the genus *Kachuga* (Rao and Singh 1987).

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BOOK REVIEWS

COLOUR GUIDE TO THE TURTLES AND TORTOISES OF THE INDIAN SUBCONTINENT, by Indraneil Das, 1991, R&A Publishing Limited, 3 Highfields Villas, Newlands Hill, Portishead, Avon, England BS20 9AU. Hardcover, 16 x 24 cm vi +133 pages, £ 38.00 +£ 2.50 mailing charge.

The diversity of life in the Indian subcontinent has long fascinated naturalists and to collect, describe, classify and catalogue its flora and fauna posed a major challenge to hobbyists and scientists alike. Reptiles and amphibians were certainly not ignored and a number of good monographs on them resulted from the workers in the British Museum and the Asiatic Society. The definitive work on the turtles, tortoises and terrapins of Asia was Malcolm Smith's *The Fauna of British India, Reptilia and Amphibia, Vol.I, Loricata, Testudines* (1931, reprinted since). Unfortunately, nearly all nineteenth and early twentieth century monographs and other publications dealt with classification, and details of the natural history of the species are scarce. After the breakup of the empires the new nations had priorities other than studying turtles, so that only a scattering of contributions to their biology were published in various journals. Over the last decade interest in turtles increased tremendously, and two books dealing with them were published independently in 1985: *Indian Turtles - A Field Guide*, by Indraneil Das, and *Handbook of Indian Testudines*, by B.K. Tikader and R.C. Sharma. *Indian Turtles'* strength is in the presentation of a lot of useful information in a concise, organised way. The text in *Handbook of Indian Testudines* adds little to the information presented by Malcolm Smith's book while most of the colour photographs depict preserved specimens and the line drawings are often so artistic that they are of limited zoological use. A number of less abundant species, such as *Pelochelys bibroni*, *Cuora amboinensis* and *Morenia petersi*, are not dealt with at all.

Now Indraneil Das delights us with his *Colour Guide to the Turtles and Tortoises of the Indian Subcontinent*, a well-written, exhaustively researched review of the turtles of Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka. As the author notes in his preface, "This work does not pretend to be a definitive work on the tortoise and turtle fauna of the region. Indeed, basic biological data on many species are still unavailable, and it would be a while before such a work can be contemplated". Nevertheless, he has done a wonderful job by presenting nearly all known data on the 5 tortoises, 23 batagurine and 8 softshell species and subspecies occurring in the area of cover age, while his treatment of the marine turtles must most necessarily be restricted to a summary of the information known about these animals worldwide, supplemented by an in-depth review of the situation on the subcontinent.

The book is set up in the standard format for a work of this scope, containing a preface, introduction, chapters on fossil history and relationships between turtles and humans, an identification key (with E.O. Moll), the species accounts, a glossary, maps, references and indexes to scientific and English names. The distribution of testudines across the subcontinent and its dependence on climate, vegetation, topography and geological history is outlined and explained in the introduction. Chapter Two deals with the rich fossil history of turtles in the region. Noteworthy is that pelomedusid turtles were represented in India up to the Miocene; this group is now restricted to South America, Africa and Madagascar. Another oddball is *Chorlakkichelys shahi* de Broin 1987, an Eocene member of the family Carettochelyidae whose single living representative occurs in New Guinea and northern Australia. Fossils of the groups which still occur in the subcontinent, the Cheloniids, Trionychids, Testudinids and Batagurines, have all been found, often in rich deposits. The most spectacular species must be *Geochelone atlas*, a tortoise that could reach a shell length of 180 cm.

Chapter Three illustrates how turtles, although they often occupy an important role in the local people's concept of the world, have been

exploited for food, medicine and ornaments whenever man meets turtle. Exploitation has become more efficient with the arrival of modern transport, and the effects are compounded by habitat alteration and degradation, so that populations of several species are now in serious decline. Legal protection of turtles exists in most countries, but they are not always fully effective. Sometimes they protect the wrong species: *Aspideretes gangeticus*, *Lissemys punctata* and *Kachuga tecta* are strictly protected by national and international laws and regulations, yet these three species are widespread and their populations do not appear to decline. In contrast, the rare *Kachuga sylhetensis* has no legal protection in either India or Bangladesh where the few known specimens come from.

The identification key is simple and easy to use, its great advantage is that it relies on external characteristics only. Therefore, one does not need to examine skeletal or palatal characteristics, which is particularly nice when dealing with live adult soft shells. The problem with keys in general is that they necessarily incorporate so many technical terms that they are of limited value to amateur naturalists or undergraduate students. This one is no exception, but using the figures following the key as well as the glossary an amateur should eventually be able to identify the specimen in hand. On the other hand, this key will be a delight to herpetologists examining zoo or trade animals or spirit specimens in museum collections.

The species accounts are excellent, and contain a wealth of information from the literature augmented by the author's extensive experience and knowledge. Each account is set up under the headings Description, Vernacular names (and their meaning), Distribution (per subspecies where appropriate), Natural history and Status and conservation. The amount of information contained in these 80 pages will provide fascinating reading for many days. The descriptions are concise and thorough, quite sufficient to establish the identity of a specimen with total confidence. Differences between subspecies are treated under this heading as well. Similarly, the ranges of subspecies are given individually in the section on the species' distribution. Details of natural history are sometimes unavailable, but whatever is known has been collected and analyzed. Status and conservation data do not always make pleasant reading, but the author presents the most recent information and indicates trends in exploitation; this information will be of great assistance to conservationists, environmental managers, legislative powers and others interested in the welfare of Indian wildlife. For his nomenclature of softshell turtles the author follows Meylan (1987) in splitting up the genus *Trionyx*; as a result, the four species from the region formerly belonging to *Trionyx* are now called *Aspideretes*. In contrast, the roofed turtles are all lumped in *Kachuga* without even a passing reference to the subgenera *Kachuga* and *Pangshura* as proposed by Moll (1986, 1987). The recognition of the Asian pond turtles as a separate family Bataguridae with subfamilies Batagurinae and Geoemydinae at first appears radical, but this arrangement is probably a better reflection of the recent advances in understanding the higher phylogenetic relationships of turtles as shown by the fossil record. In the account of *Cuora amboinensis* we learn that three subspecies may exist, and indeed, Rummler & Fritz (1991) just published a paper in which they recognize *C.a. amboinensis* (Moluccas, Sulawesi, Philippines), *C.a. couro* (Sumatra, Java), and *C.a. kamaroma* (Mainland Asia, Borneo). Extremely valuable for captive breeding attempts are data on the timing of the reproductive cycle (where known) for the various parts of the range of some wide-ranging species. These cycles generally depend on the monsoon, so bringing together a number of animals of the same species from areas with different climatic regimes decreases the chances of successful reproduction; additionally the resulting mixing of genes may not be exactly beneficial. The opportunity was missed to include averages and ranges of sizes and weights, which is especially informative for nesting sea turtles; only (worldwide) maxima are given. For example, to write of the Hawksbill that "The species reaches 1m and weighs 135 kg." is somewhat optimistic considering that Pritchard & Trebbau present average sizes of 66 - 89.5 cm for

nesting females of 13 populations, while 384 mature females from these populations range from 53.3 to 93 cm. In my opinion the book would have been enriched if synonymies had been included, but these were considered too uninteresting by the publisher. For these we will continue to rely on Smith (1931).

Amidst so much information there are only a few incomplete or wrong statements. In the key, the bicuspid mandible at junction 28 must be a bicuspid upper jaw (p.17). The bridge of *Chelonia mydas* bears four *infra* marginals rather than marginals (p.27). Kabraji and Firdous' (1984) data, reporting incubation periods of 22 - 166 days for eggs of *Chelonia mydas* in Pakistan, seem too unorthodox to be repeated without cautionary remarks (p.29). The supracaudal or twelfth marginal scutes of *Indotestudo elongata* and *I. forstenii* are undivided (as noted in the key), not paired (as given in the species descriptions). A number of typos can be expected. These are not a problem when they occur in the text but can become serious when they affect measurements etc. An 18.5 cm *Hardella thurjii* cannot weigh 11.27 kg. Often egg and hatchling sizes are mixed up between mm and cm: A *Testudo horsfieldii* hatchling measures 42 mm, not 42 cm. Exploitation of *Caretta caretta* is illegal, not legal. A number of states on map 3 have been given wrong numbers (23 = Goa, 24 = Karnataka, 25 = Kerala, 26 = Tamil Nadu).

The overall quality of the book is excellent: the paper is of good quality, solidly bound, and the hardcover seems tough enough to survive even several years in the field. The contents make a very compact impression, the letters are small and the text blocks follow closely. The writing style is so concise that the same amount of data could easily have produced a book with double the number of pages. The 66 colour photos are collected into 16 plates and the frontispiece is a watercolour of *Kachuga sylhetensis*. The photos are good, a few show some wash-out because they were taken in midday sun but these are well compensated for by the others, which include some of the finest turtle portraits available. Admitted, the price of the book is high, but one should realize that producing a small edition of a high- quality technical book with good colour plates is a very expensive process as well as a risk to the publisher, particularly when it is not sponsored in any way.

In conclusion, *Colour Guide to the Turtles and Tortoises of the Indian Subcontinent* is a wonderful book, filled with hard-to-find facts, details and information. The author deserves full praise for his persistence in collecting virtually everything ever written or known about the turtles of the region. Just as great an achievement is that he has managed to bring together colour photographs of living specimens of virtually every species and subspecies. For anyone with a serious interest in turtles in general and those of the subcontinent in particular it will be well worth obtaining this book, because it will be the standard reference on this subject for the rest of the century and well beyond.

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ZOOGEOGRAPHY OF INDIAN AMPHIBIANS: DISTRIBUTION, DIVERSITY AND SPATIAL RELATIONSHIP by S.K.Tiwari, 1991. Today and Tomorrow's Printers and Publishers, New Delhi. 187 pp. Hardbound with dust jacket. ISBN 81- 7019-391-5 (India) and ISBN 1-55528-239 (U.S.A). Price Rs.295.00 or $49.00. Available from: Today and Tomorrow's Printers and Publishers, 24B/5, D.B. Gupta Road, New Delhi 110005, India and Scholarly Publications, 7310, El Cresta Drive, Houston, Texas 77083, U.S.A.

The volume under review seems to have caught the herpetological world by surprise! Written by a zoogeographer, this is not a "mine of information", but is a minefield for the uninitiated.

The author is a professor of geography in the Government of Madhya Pradesh's Collegiate Education Services, his previous works including "Readings in Indian Zoogeography" and "Zoogeography of India and S.E. Asia" (both published in 1985).

Hardbound with a startling yellow dust jacket, the binding of this book is superior to the M.A. Smith volumes reprinted by the same publisher. However, paper and printing are as poor, some of the fold-out maps in the copy in my hand already being creased and warped. In addition, many of the pages as well as the dust jacket have an interesting reddish-brown stain.

The work is divided into six chapters, the first essentially an overview of amphibian biology, including brief commentaries on their shape, size, reproduction, distribution and economic value. The second chapter is concerned with the evolution, past distribution and classification of the world's amphibian fauna, relying heavily on published works. The third deals with the families of amphibians represented in India, and is perhaps the most useful section of the book. It is, however, here that references are made too frequently to Darlington (1957). The fourth chapter is titled "Systematic distribution of Indian Anurans". As with the previous chapters, I could not detect new data or interpretation; it depends heavily on Inger and Dutta's (1986) checklist.

The author's familiarity with the literature on the biogeography of the region's fish fauna is evident, and he occasionally draws several useful parallels with the distribution of the amphibian fauna. However, much of the data used in the synthesis are derived from Inger and Dutta's (1986) review which is unlisted in the References section, and no evidence of hands-on experience is evident (if one excludes a passing comment on school trips by the author thirty years back). Another work frequently quoted is Noble (1931), although the more recent work of Duellman and Trueb (1986) is not.

It is unclear what the maps set out to achieve: the information they provide is certainly not always accurate. The distributional map of the hylids (map 4; page 63) shows the presence of these Palearctic frogs all over peninsular India and Southeast Asia (when, as correctly stated in the text, a single species, *Hyla annectans*, occurs to the northeast of the Indian region); the map of the microhylids (map 6; page 69) excludes northern India and Pakistan. Caecilians are shown occurring all over peninsular India (map 2; page 23), whereas members of this group, within the peninsula, are restricted to the Western Ghats.

Inconsistencies in nomenclature are also evident: For instance, page 93 lists ranid species of the genus *Tomopterna*, including *T. breviceps*, which is earlier (page 83) considered a member of the genus *Rana*.

In the penultimate chapter (Regional Distribution), the author sets out to describe the affinities of the Indian amphibian fauna. This he clearly fails to do concisely, getting lost in mostly unnecessary details about climate and vegetation. The chapter continues almost without a break into the last section (Chapter Six) on regional patterns of distribution, which discusses the various biogeographic zones within India. Once again, the author loses sight of the primary goals of the chapter, and dwells on describing tropical seasonal forests and tropical rain forests (of the latter category, very little are represented in the country). The book concludes abruptly: perhaps the author realised the futility of writing it.

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SNAKES OF MEDICAL IMPORTANCE (ASIA-PACIFIC REGION) by P.Gopalakrishna kone and L.M. Chou (Eds.) 1990, Venom and Toxin Research Group, National University of Singapore.

When you encounter a new book on snakes you naturally want to find some original material, good photographs and answers to questions that have been bothering you. In the case of this 670 page volume there is plenty to satisfy the herpetologist or medical doctor who may have to deal with a snakebite.

Predictably however, the standard of information and writing is inconsistent. Australia, for which we have a half a dozen good books on snakes and more information on snake and snakebite than any of the other Asia-Pacific countries, takes up over a quarter of the book. The authors have used beautiful photos, drawings and distribution maps to give a concise presentation of the snakebite in Australia which will be of considerable value to a doctor, layman or herpetologist.

At the other end of the scale are chapters like the four page summary on snakes of medical importance in the Philippines. The chapter on Taiwan is similarly disappointing and these are both countries from which there is very little information on snakes and snakebite. In the chapters describing the snakes, most authors follow the format which is comprehensive and easy to follow but a few do not.

Some of the most exhaustive work done on snakebite in the Asian region has been by Dr. Yoshio Sawai and his colleagues of the Japan Snake Institute. Snakebite statistics from many of the countries in this area are based mainly on their work. It would have been very useful to include a chapter by Dr. Sawai which compares the snakebite problem in the region. This would provide a clear overview of the main species responsible and where more research and effort need be applied to manage the problem of venomous snakebite.

It was especially gratifying to see the chapter on the dangerous snakes of New Guinea about which virtually nothing has been written in recent years. Much still needs to be learned, especially about species like the small-eyed snake *(Micropechis ikaheka)*.

The final chapter by Professor David Warrell is an excellent wrap up and is especially valuable for the medical man who may be called upon to deal with the complications arising from envenomation. Some of the photographs are horrific but they are instructive and apparently some of the "milder" clinical photos in the author's collection. It would have been valuable to have a comprehensive chart of available antivenoms in the region covered. In addition, it would be useful for physicians to be aware of the relative qualities of antivenom. It has been reported by Jim Glenn and other researchers at the V.A. Laboratory in Utah for example, that antivenom assays indicate that the Thai Red Cross and Haffkine antivenoms are more likely to result in allergic reactions in a patient.

In general "Snakes of Medical Importance" is a well produced and useful volume that should be available to doctors and others who treat or may experience snakebite.

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LIZARDS OF THE ORIENT: A CHECKLIST by K.R.G. Welch, P.S. Cooke and A.S. Wright. Robert E. Kreiger Publishing Company, Malabar, Florida, 1990. 162 pp, hardbound, price $21.50. Available from: Robert E. Kreiger Publishing Company, Malabar, P.O. Box 9542, Florida, 32902-9542, USA.

"Here be dragons!" It is with these chilling words that ancient western cartographers mapped the unknown edges of the Mysterious East.

Dragons, a myth in the west, can sometimes be a terrifying reality in the east. As recently as 1912, Ouwens formally described the largest living member of the Order Sauria, the Komodo dragon *(Varanus komodoensis)* from the Indonesian islands of Komodo. Known to exceed 3 m in total body length, this gigantic beast is now also known to occur in the adjacent islands of Rintja, Padar and Flores, feeding on a variety of invertebrate and vertebrate prey - which very occasionally includes man!

The lizard fauna of the Orient, comprising, as defined by the authors of the volume under review, "Pakistan east to China, south through Asia, to include Japan, the Philippine Islands, Indonesia and Papua New Guinea", is very imperfectly known. This is surprising when we have spectacular forms- some with horns on the head, others that open "wings" and glide between treetops, change colour...and there are the sand-swimmers and club-wielders.

One reason for the lack of general knowledge about lizards of our region is certainly the paucity of books, and this one fills an important gap. Taxonomists, ecologists and biogeographers will find *Lizards of the Orient* invaluable, because of the near-complete listing of valid species from all families of the region, a section on the primary descriptions and latest taxonomic descriptions, distributional data. This is Kreiger's very latest in the series on herpetology, a companion volume to the first author's "Snakes of the Orient: a checklist". Both volumes are attractive library additions, with fake reptile skin binding, embossed gold titles and beautiful illustrations.

Following a short introduction, the book starts with a family-wise listing of species and subspecies. The account of each taxon includes the name of authority, original name, a practical reference to the type description, type locality, and distribution. Nomenclature follows the most recent reviewers of individual groups, and in the case of problematic taxa, the scheme in Smith's (1935) Fauna of British India, Volume 2 has been followed. The style is simple and species and subspecies as well as higher taxanomic categories can be located with minimum sweat. An invaluable bibliography of primary descriptions of lizards and an index to generic, specific and subspecific names concludes this work

Omissions of taxa are to be expected in books like these which deal with the fauna of a large geographical region, with its local, often not widely distributed or abstracted, journals. The following species are unlisted in the checklist: *Mabuya nagarjuni* Sharma, *M. clivicola* Inger et al., *Hemidactylus porbandarensis* Sharma, *Lygosoma pruthi* (Sharma), *L. ashwamedhi* (Sharma), and *Cnemaspis goaensis* Sharma. Perhaps the new edition could incorporate these absentees, plus the new forms described since the publication of this checklist.

The book compares well with the other recently published, somewhat similar work, that of Sokolov (1988: Dictionary of animal names in five languages. Amphibians and reptiles. Russky Yazyk Publishers, Moscow), which does not cite primary descriptions or distributions of the species listed, although the work is broader in scope, covering all valid species of amphibians and reptiles of the world. *Lizards of the Orient*, a less ambitious but more comprehensive venture, may thus be more useful, especially to lizard systematists. It is a very worthy successor to Welch's earlier snake checklist. My review copy already looks well thumbed.

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COLOUR GUIDE TO THE SNAKES OF SRI LANKA by Anslem De Silva (1990), R&A Publishing Limited, 3 Highfield Villas, Newlands Hill, Portishead, Avon, England BS20 9AU (price not given)

Our part of the world doesn't have its share of herpetologists and the dearth of literature both scientific and popular is apparent For this reason and others, it was gratifying to see Anslem de Silva's *"Colour Guide to the Snakes of Sri Lanka"*. Sri Lanka has 93 species and subspecies of snakes, half of which are endemic to the island and so far there are no concise, popular books to aid in their quick identification.

The book has chapters on the species and their characteristics as well as on the interaction of humans and snakes in Sri Lanka and on snakebite. The format in the descriptive chapter of the species is well planned and concise and the literature well reviewed and up to date. In the chapter on "Man and Snakes" it should perhaps have been mentioned that many of the beliefs and myths had their probable origins in adjacent India.

There are twelve colour plates in De Silva's book illustrating 53 species of Sri Lankan snakes. Some of the snake pictures are excellent and clearly identifiable despite their small size. Abo a third of the photos do not contribute much this otherwise well produced volume, but the d ficulties of obtaining pictures of more obscu forms is appreciated.

The final criticism of the "Colour Guide the Snakes of Sri Lanka" is the general gramm of the writing. The book is going to be read wi interest by herpetologists and others from ma parts of the world and the author and publish owe it to these readers to edit the text to t highest possible standard of writing.

It is hoped that once a complete collection good colour photos of the Sri Lankan snakes available to De Silva, we will see a second editic

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NOTES

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SUSPECTED CASE OF DEATH BY PIT VIPER BITE

Past experience and a brief review of the literature indicates that fatalities from Asian pit viper bites are infrequent. In China for example, a single death due to Mamushi *(Agkistrodon blomhoffii brevicaudus)* was reported between 1973 and 1985 in Haining County, the white-lipped pit viper *(Trimeresurus albolabris)* is responsible for one known death and the five pace snake *(Agkistrodon acutus)* killed two persons in the same period. The Andaman pit viper *(Trimeresurus purpureomaculatus andersoni)* causes fairly frequent bites in that group of islands, and while severe local symptoms are reported (including one victim bitten in the face and one amputation (Whitaker, unpublished obs.) there are no reported deaths. The Malayan pit viper *(Calloselasma rhodostoma)* on the other hand, was responsible for 13 fatalities at 15 hospitals in Thailand in three months in 1980 and non-fatal bites are most noteworthy for the onset of necrosis (dry gangrene).

Almost nothing is known about the life history and venoms of many of the less common pit vipers such as the Nicobar pit viper *(Trimeresurus cantori)* endemic to the Nicobar group of islands in the Bay of Bengal. Recently a preserved specimen of this snake (a female, 725 mm in length) was sent to the Irula Snake Catchers Cooperative Society in Madras from Nancowry Island in the Nicobars for identification along with the post mortem examination report of an apparent snakebite victim. The following is a summary of the report.

Victim was a male, 48 years old, described as "stout" and in good physical condition. He was apparently bitten in the late morning or midday while walking in the jungle and was discovered at 2.15 p.m., dead near the beach with the dead snake close by. Two marks, resembling fang marks with serum oozing from them were present on the left leg, just above the ankle; however, there was no edemal swelling or necrosis. Clotted blood was present below the suspected fang punctures.

The victim's entire gastro-intestinal tract was markedly congested and the stomach contained about 300 ml of frank blood (with "a faint smell of alcohol" the report states). The attending Medical Officer summarized his findings as follows.

"As a result of the postmortem examination the conclusion arrived at is that the deceased could have died due to hemorrhagic shock from massive gastro-intestinal hemorrhage which could have been due to poisonous snakebite".

In general, as stated above, pit viper bite does not usually result in death. However, given the circumstances of a person with a history of gastro-intestinal bleeding (a complication of alcoholism) or other condition that could be aggravated by the injection of a hemorrhagic venom and the relatively large size of the snake, a Nicobar pit viper should be considered a potentially lethal species. It is also possible that the venom toxicity of some of these pit vipers is considerably higher than yet reported. It would be advisable that the venoms of these species which are now going to be encountered more frequently by humans as the islands develop be studied both for their lethality as well as their possible medical value.

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MUGGER IN A FACTORY LAKE IN GOA

INTRODUCTION

Mugger Lake is a 22 acre man-made lake within the Ciba-Geigy Santa Monica Complex supplying water to the factory. It was formerly linked with the Cumbarjua Canal which links the Manori and Zuari rivers. There have always been crocodiles in the Cumbarjua Canal, but nowadays there is severe human pressure on all the places where crocodiles once lived, a result of which a number of crocodiles have taken up residence in Mugger Lake. The creation of this lake and protection of the approximately 40 acre adjacent marshland has not only benefitted crocodiles (and fish, turtles and acquatic vegetation) but it has also encouraged many species of birds, including migratory waterbirds, to use the area as a feeding and nesting ground. In addition, there is reportedly a small herd of wild pig and a number of other mammals, reptiles and amphibians which depend on the ecological integrity of the Ciba-Geigy complex. Such protected "islands", surrounded by rapid development, become more and more important for Goan wildlife and should be encouraged.

FINDINGS

On this short visit it was observed that a small, healthy, breeding population of the Indian mugger crocodile *(Crocodylus palustris)* exists in totally protected conditions at Mugger Lake in the Ciba-Geigy Santa Monica factory compound, just south of Panjim, Goa. During daytime surveys on the 19th and 20th of February 1991, 6 adult sized (2 .5 metre length) crocodiles were seen and at night six juvenile (1 metre length) and 4 adults were seen. It is estimated by these sightings and ground surveys around the lake that there are at least 25 crocodiles in the lake of all age classes.

There are still small numbers of wild crocs in the Zuari River and Cumbarjua Canal, adjoining Ciba-Geigy (A.G. Untawale, pers. comm.). The uncertain future of wild crocodiles makes this protected population of considerable importance as a permanent repository of the species in the area. The offspring bred here will find their way into the Canal to recruit the wild population. Though they will occasionally dogs and goats, there is no record of a mugger crocodile attacking a human in Goa.

The crocodiles in Mugger Lake feed on fish, frogs, rats, birds and insects. The population is likely to remain in an equilibrium determined by the area of water, food resources and the social hierarchy (i.e. larger, dominant crocodiles will chase out the smaller ones).

35 species of birds were seen (out of a reported total of 76 species recorded here) including prominent water birds like the lesser adjutant stork, cormorant, cattle egret and night heron. It was noticed that the few trees around the lake are damaged from overuse by the birds.

Evidence of a number of species of mammals (including wild boar, mongoose and civet cat), reptiles (cobra, ratsnake, monitor lizards), fish (catfish, barb, eel) were seen, indicating a rich environment, virtually an island surrounded by rapid development. The swampland adjacent to the lake is one of the main attractions to the numerous birds that come to the Ciba-Geigy factory complex and represents one of the few remaining bits of wetland in the area.

In general the protected, wild portion of the Santa Monica plant is unique since there is no grazing or other trespass, affording excellent cover and habitat for a surprisingly high diversity of plants, animals and birds. There are several simple steps that can be taken to enhance the ecological value of the plant area: a nursery of local trees can be established to plant the edges of the lake. Corridors of undisturbed vegetation for smaller animals and birds and for crocodiles to move to the canal are needed. It was also recommended that a study of the crocodiles and general limnology of the lake and contiguous swamp be undertaken to refine the above suggestions.

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Whitaker's sand boa Eryx whitakerii was described in 1991, yet it is a fairly common, conspicuous snake ranging along much of the western coast of India. This docile boa has characteristics of both of India's other two erycine snakes, Eryx conicus and Eryx johnii.

Nikhil's kukri snake Oligodon nikhilii was described in 1982 on the basis of one specimen collected near Kodaikanal in the Palni Hills by a child. It was found in one of the distinctive endangered shola forests of these hills.

The Andaman water snake Xenochropis piscator is a snake with numerous variations of pattern. Some are entirely blotched, others lined (such as this specimen) and others have a mix of both basic patterns.

The Andaman pit viper Trimeresurus purpureomaculatus andersoni is common throughout the islands and causes a number of non-lethal bites. It varies greatly in colour and pattern, including among siblings of a single litter.

OVERVIEWS

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DISTRIBUTION OF *GAVIALIS GANGETICUS*

Gharial are known to be endemic to the rivers of Indian subcontinent but fossil history shows that they occurred outside this region before continental drifts and the separation of Gondwana land (1) (2) (3) (4) (5). In the recent past gharial occurred in the northern river systems of Indus, Ganges, Brahmaputra and Irrawady (6), and the southern river systems of Mahanadi (6), Godavari (7) (8), Narmada (9) and Krishna (10). Before 1975 adequate or reliable information on the various extant populations were lacking. Therefore, one finds categorical statements like gharial "has never been able to reach Godavari, Tapti and Nerbudda (Narmada) systems, even though the northern tributaries of these rivers originate very close to the sources of rivers joining the Ganges" (11). The specific name *gangeticus* has built in a very strong impression since about three centuries that gharial occurred in the Ganges and have spread out from here. Another such controversial view is that the "distribution is compatible with the idea of spread from India" (10). Based on geologic and recent records it appears that the range of the gharial has gradually shrunk and even the extinct or near extinct populations in the south are remnants of a once very wide range. The flow of rivers and the crocodilians in these rivers do not recognise national and international boundaries. However, while describing the population distribution of a species we generally resort to country by country status. Such comparison can establish a spirit of healthy competition among the range-countries, doing good to the species.

BURMA

During the Pliocene, gharial occurred in Burma (12) but in recent period the only record is from the Irrawady river system by Burton (13) who records a specimen, 16'16" (495 cm) long, shot at the mouth of Malingatha, a tributary of the Sweli River, Upper Burma. This report and as such the information for Burma is often viewed with suspicion because of a lack of further confirmation. However, it is also agreed that there has been no proper survey in the locality of Maingatha.

BHUTAN

The status of gharial is unknown in Bhutan. It is thought to be probably extinct (14) or if occuring then may be as "an occasional specimen in the Manas River, Manas National Park (15). Bustard (16) has reported the regular sighting in 1977-1978 of an introduced individual in Manas, and has concluded that gharial is otherwise extinct in Bhutan.

PAKISTAN

Although the Indus River is within the distribution range of the gharial, doubts regarding the species' continued survival were expressed after the report by Minton in 1966 (17). Minton stated that "except for a questionable sight near Schwan, I didn't encounter the Gavial during my stay in (West) Pakistan". The latest report from Pakistan is by Ashiq Ahmed (18) of the Pakistan Forest Institute, Peshawar, who states gharial have been reported only from lower parts of the Indus. A recent survey there "revealed that few gharial, if any, might have been left here and there, while main populations are now extinct from their previous habitats in Sind". Rao (19) reported that gharial were seen in the Indus in the 1930s. Whitaker (15) stated an estimate of 30 wild gharial in the Indus. The main population of about 20 occur in Nara Canal, which is 160 km long, 100 m wide, 6 m deep and forms a part of the Indus River Dolphin Sanctuary (14). The other populations are stated to be around Gudder Barrage (Sind) and Taunsa Barrage (Punjab) (20) (21).

BANGLADESH

During the 1970s the gharial was believed to be extinct in Bangladesh (20) (22). Hussain's (23) report that gharial occurred in the Ganges and its tributaries in Bangladesh had remained un-

noticed. Khan (24) gave the first authentic report regarding the continued survival of gharial in the Padma (Ganges) and Jamuna (Brahmaputra) rivers. These have later been further confirmed by Whitaker (15) and Wakefield (25). Khan (26) stated that in a total population of 20, the main population occur in Padma which during the monsoon has a chance to meet the population from Jamuna because of confluence of the two rivers in flood. Breeding populations occur near Rajshahi town, Sirajganj and Gaibandha (26), near Char Mukhterpur village close to Indian border (14), Char Khidipur, Diar Khidipur and Charghat (25).

A survey conducted during February-March 1985 (27), recorded 18 gharial in the Padma River at Charghat, Charkhidipur and Godagari under Rajshahi district, 4 in the Jamuna River at Daokopa, Delabari, Archarpare, Pagrarchar, and Shariakandi, Bogra district, and 6 gharial in the Brahmaputra River at Kuirghat, Gupinath, Rasulpur, Sonabhanimukh and Gidari, Gaibandha district. district.

NEPAL

Major populations of gharial occur in the Kali-Narayani (= Gandak in India) rivers. In 1977, at least 16 nesting females were confirmed (28) and 53-66 young and adult gharial were estimated (29) (30). Groombridge (14) has quoted H.R. Mishra's estimations of 50-55 adults and 50 young in the Narayani, and 10-15, perhaps more, adults in the Karnali (= Girwa in India), particularly at Chisa Pani Gorge. The nesting sites in the Narayani in 1977 were at Bhimban, Kathaun, Pitaonjighat, Sasana, Veluani, Sikroli and the Rapti River confluence. The site in the Kali was at Deoghat/Haridabagar (28). Group basking was seen by Sharma (29) in the Narayani at Kharkhareghat, Bondar Jhula Island on both north and south faces, Amaltari, Male Bagar, Kathauna Bagar and Bhelauji Bagar, and in the Kali at Deukhur Bagar. Bustard (31) mentioned nesting sites during 1978 at Tamaspur, Bandar Jhula and Deoghat. The Narayani, particularly before the Indian border, is wide, meandering through the plain and often changing its course (32). Within the Chitawan National Park, I. Taylor (14) had seen 15 adults in a single day. Small and scattered populations are also stated to occur in the Babai, Rapti, Rapti Doon, Makali and Kosi rivers (22). Mishra (14) estimated 65-70 adult gharial in Nepal.

INDIA

Except the Mahanadi, gharial are extinct from all other river systems of the southern range. The last gharial were seen in 1971 in Sileru of Orissa which is a tributary of the Godavari (8). In the main Godavari gharial were last reported in the 1960s (7).

Mahanadi system

The river originating in Madhya Pradesh has its major flow right across Orissa State upto the coast of Bay of Bengal. Two rivers that form the delta with the Mahanadi are the Brahmani and Baitarani which once had good gharial populations (8) (33) but was never before referred to in the literature. The last surviving gharial of the Brahmani was shot in 1975 and occurrence in the Baitarani dates back to "10-20" years before 1982 (33).

The Mahanadi River has always been quoted under traditional references to the distribution range of the gharial (34) (6) (35) (36) (37) (28) (38). During and before the 1950s gharial were "abundant" in the stretch now upstream of the Hirakud Dam (39). Gharial were last sighted in the reservoir in 1975 in Sini nullah and near Chaurasimal village (40). On the northern side of the reservoir, the Ib River, a tributary of the Mahanadi, used to have gharial and mugger *(Crocodylus palustris)* before the setting up of a paper mill at Brajarajnagar in 1931. During the monsoon, gharial and mugger were sighted in some years until 1966 near Rampella village. The polluted water is now unsuitable for fishing or agriculture during the dry season.

Below Hirakud Dam there are a few tributaries like the Tel, Baghmati and Badanadi which do not have resident gharial but do some times get monsoon-migrants. Resident gharial from the dam downstream to Boudh are also rare and usually monsoon-migrants. Downstream from Boudh to the beginning of Satkoshia Gorge surveys conducted in 1975-77

(40) indicated the occurrence of a total of seven gharial including one male (3.6-3.9 m), a female (3 m) and others in the size range 1.5-2.7 m. Six out of these seven were surviving when releases commenced under the conservation programme in April 1977.

Resident gharial within the limits of the Satkoshia Gorge Sanctuary included 2 females (3.6 m and 4.5 m), 2 males (5.4 and 6.6 m) and one subadult 1.4 m. One adult of each sex were displaced after 1977 and were not seen since. Downstream from the sanctuary, there was only one report of a 2.4 m gharial. n the 1950s gharial were "abundant" near Kendrapada-Patamundai and Kujanga areas and in 1930s Derabasi near Salepur was famous for gharial and "gharial worship". These places often get tidal water and here the river is brackish.

Between 1975 and 1983 there was no successful breeding of gharial in the Mahanadi. From 1984, wild breeding has resumed with a clutch of eggs found each year close to Majhipada nullah, about 2 km upstream from the location of Gharial Research and Conservation Unit at Tikerpada, in Satkoshia Gorge.

Occurrence of gharial in the Ganga (the Ganges) covers the states of Uttar Pradesh, Madhya Pradesh, Bihar and West Bengal. The Yamuna, Ghaghara, Sarada, Rapti, Koshi and Gandak are the main Himalayan-fed tributaries of the Ganga. The peninsular tributaries are Chambal, Sindh, Betwa, Ken and Son from the south and Damodar from West. Among the non-Himalayan tributaries (except the Son and Damodar which are direct tributaries of the Ganga), all others are tributaries of the Yamuna. Descriptions of the gharial population in the main Ganga River are anectodal, and lead to the belief that with the gradual settlement of civilization as a result of expansion from the Indus Valley, resident populations of gharial may have dwindled from the main river. Breeding has not been reported from the main river, but monsoon migrants are known in the stretches between Garh Muktesh war-Kanpur, and Allahabad-Mirzapur (41). The largest gharial in recent years was a 5 m female electrocuted and found dead near Kanpur in 1974 (42).

Yamuna sub-system

Before the formation of geologic ridges in sub-recent times, the Yamuna used to be linked to the Indus system (43). It is also possible that present-day peninsular tributaries of the Yamuna were once the direct tributaries of the Ganga. The abundance of gharial at one time in the Yamuna is reflected by Hornaday (44) that 22 gharial were counted in just two hours. The Yamuna no longer has a resident population of gharial in its main course. Recent sightings are seasonal near the Ganga confluence at Allahabad (22) and the chances of such sightings have potentially increased after gharial release programmes were taken up in the National Chambal Sanctuary and Ken Gharial Sanctuary.

Chambal. In the literaure there is no credit to the Chambal River as a gharial habitat (45). Failure of such recognition is mainly due to inaccessibility through the deep ravines and very little social contact of the resident human population with people outside. Local informants when contacted in recent years, speak of the species' once extremely high concentration in the river. The Chambal originates from the Vindhya Range in the state of Madhya Pradesh. It courses through Rajasthan state and then forms the border first between Rajasthan-Madhya Pradesh and later between Uttar Pradesh-Madhya Pradesh, to finally flow through Uttar Pradesh until its confluence with the Yamuna at Barhi. At the confluence, the Yamuna is like a small rivulet and much of its downstream flow is contributed by the Chambal. Commencing from the 1960s the flow of water in the Chambal has been checked by the building up three successive dams (Gandhi Sagar, Rana Pratap Sagar and Jawahar Sagar) and the Kota barrage. The reservoir of Jawahar Sagar Dam and the adjoining streams, particularly the Brahmani are within the Jawahar Sagar Sanctuary since 1975, where up to eight adult gharial are estimated to occur (45).

The National Chambal Sanctuary was delineated in 1979. The Sanctuary holds the largest extant population of gharial. It extends

from Keshoraipatan (30 km downstream to Kota) to Pachhnada (the confluence of the Yamuna with Sindh, Pahuj and Kunwari streams. This confluence is 15 km downstream the Chambal-Yamuna confluence).

The entire length of the Chambal with its tributaries the Brahmani and Banas in the upper reaches, and Sindh and Pahuj in the downstream, are reported to have supported gharial "in the past". In recent times, except for the main Chambal, the tributaries are almost dry for most of the year and therefore the distribution of gharial in this range has shrunk to the main river alone.

Estimates given for the population of gharial in the Kota-Barhi stretch of the Chambal are only partially complete (22) (46) (41) (47) (48) (49) (15) (14) (50). Based on this information, the 1977-78 figures for the stretch from Kota (Keshoraipatan) to Pali were 1 pair of breeding adults (at Pipalda) and 7 younger gharial, and for the stretch from Pali to Barhi, 9 males, 21 females, 43 of 1.2 - 3.0 m and at least 34 less than 1.2 m, a total of 10 males and 22 females between Kota and Barhi (45). Based on surveys conducted in 1983-85, Singh (45) has highlighted the trend of the increasing gharial population in the Chambal. The nesting potential in 1985 was above 35 for 39 females and 10 males. Gharial restocked under the conservation programme are now adding to the resident breeding potential.

Betwa and Ken In Uttar Pradesh, Betwa gharial were considered to be "extinct or near extinction" by 1978 (41) and recent reports from Madhya Pradesh treat the species as extinct in the upper reaches. Similarly, in the Ken before 1978, gharial were extinct in Uttar Pradesh (41) but a survey conducted in 1980 indicated the spoor of a single large gharial and reports about the occurrence of three others were available (51). A gharial sanctuary has been declared along the Ken since 1982.

Western Himalaya Sub-system. One of the early descriptions of crocodilians in this tract is by Champion (52) with reference to what was then known as the Oudh. He writes, "Crocodiles, both the common mugger of India and the long-snouted gharial, are extremely common in the sluggish streams and numerous lakes of the Oudh jungles, and I have counted as may as forty-five in a single day lying out on the banks of the Mohan river - a small stream which forms part of the boundary between India and Nepal". The Mohan River is a tributary of the Kausiala which in turn is a tributary of the Ghaghara. In this region, gharial are mostly "restricted to a 3-5 km stretch of Girwa adjoining compartment 2 from about one kilometre above the temporary bridge at Katernyaghat" (41).

Ramganga. This river leaves the Garhwal hills and reaches the Gangetic Plain near Kalagarh where a huge earth dam was completed in 1974 after a labour of sixteen years. The reservoir of 80 sq. km has submerged the best gharial habitats. Till the 1960s, gharial were present in good numbers. "A census carried out in 1965 indicated the presence of 15 adult gharial" (41). A survey in 1974 (53) showed the survival of only four adults. In the downstream area where the river is dry on account of the dam, Singh (41) reported "only a few isolated gharial" in 1978 in Bedaur and Shahjahanpur districts. Such isolated gharial are now considered extinct unless replaced periodically by gharial restocked upstream.

Girwa. The river includes a stretch of 18 km that has been in the Katerniyaghat sanctuary since 1976. There were 14 gharial during a survey conducted in 1975 and a sign of increase in the population was noticed in the following years when gharial migrated downstream due to disturbance from surveys for a dam in Nepal (there the riiver is called the Kárnali). There were 2 males, 7 females and 25 young gharial in 1978 (54), 2 males, 7 females and 19 young gharial in 1979 (55). Due to the restocking programme the population is on the increase but the habitat is too small to sustain major numbers.

Ghaghara. The name of the river is given to the tributary formed from the confluence of Kausiala and Girwa. Since over a decade, adult gharial were not seen in this river and even the monsoon-migrants have become rare (41). Singh

Present day distribution of gharial *(Gavialis gangeticus)* **in the Indian subcontinent.**

Rivers: 1. Indus; 2. Chambal; 3. Karnali-Girwa; 4. Ramganga; 5. Kali-Narayani-Gandak; 6. Koshi; 7. Son; 8. Mahanadi; 9. Manas; 10. Brahmaputra; 11. Padma-Yamuna.

(41) estimated the occurrence of five isolated gharial and the last definite record was a 1.3 m juvenile caught by a fisherman in October 1975.

Rapti. The resident population is now extinct. Migrant gharial from Nepal are sighted in some years (41).

Central Himalayan Subsystem. The Gandak and Koshi are the main tributaries that supported gharial in this region.

Gandak. The Narayani River from Nepal enters India at Triveni where it joins the Panchnad and Sonha and is called the Gandak. With the setting up of the Gandak Barrage movement of gharial from the Narayani has been restricted. V.B. Singh (41) has quoted Thomas W. Webber (The Forests of Upper India, 1902) that in those days "20 or more" gharial used to bask in the mid-river sand bars along the stretch flowing through the Doma forests of Nichlaul Range in Gorakhpur district bordering Bihar. Sahi (56) photographed a gharial, about twenty feet long (6 m), some ten kilometres from the barrage in 1972 November. Three gharial, including a female about 3 m long, were seen in 1975 near the Tailfall gate on the main Gandak West Canal (41). During the monsoon gharial used to be seen in "small numbers (less than 5)" at the Gahanu and Bhainsaha Ghats of the river (41). With the barrage coming up and the reduction in populations from adjacent tributaries, the continued appearance of gharial in Gandak is doubtful.

Koshi. The best account is given by Biswas (57). The survey conducted in 1968 revealed the occurrence of good populations in the past and sightings in October of one with two young and one of 18 feet (5.4 m). An estimate in 1976 by the Madras Snake Park Trust (46) put the population of gharial in the Gandak and Koshi at less than twelve. There has been no recent report of gharial from the Koshi.

Peninsular Subsystem. Whitaker and Daniel (22) mention the rivers Mahanadi, Chandia and Tons and Singh (41) about the Son and Ton as having gharial. However, besides the Mahanadi and Son, gharial have disappeared from all the others (58). In 1981 six were sighted during a short visit to the Son (J.J. Dutta, pers. comm.) and a detailed survey after the establishment of the Son Gharial Sanctuary in 1982 has revealed the occurrence of 18 gharial but without an adult male. Restocking of young gharial through the conservation programme has been taken up recently.

Brahmaputra System. Abundance of gharial in the Brahmaputra is highlighted in old accounts (59) (60). The survey report of the Madras Snake Park Trust (61) quoted a letter from H.K. Dodwell of the Panitola Tea Estate in Upper Assam to Mr. W.A. Stuff, Editor of the 'Monthly Review' in Calcutta (21 March 1973): "These alligators (gharial) used to be comparatively common on the Brahmaputra and its large tributaries in the Assam Valley, but they have now disappeared from most of their former haunts, and I fear they should join the ranks on the 'danger list'. The surveyors (61) had received reports of sightings from previous years and had seen evidence of young gharial in Subansiri tributary. In recent years, gharial are reported to be breeding in the tributaries Subansiri (Arunachal Pradesh), Dikho (Assam, Nagaland), Dhansiri (Assam), and Doyong and Disarg (Nagaland) (58). These reports gain more support from the recent revision of opinion about gharial in Bangladesh. The estimated population of gharial in the Brahmaputra is 50 of all sizes (58).

EPILOGUE

From the early 1970s all 'range-countries' for gharial have become conscious about the depleted status and range of the species. India took up a massive management programme to conserve the species (62, 63). Today the species exists in safe numbers in the Chambal, Girwa, Ramganga and Son rivers. The programme for the Mahanadi, where the entire technique for gharial management was evolved, have been reviewed in the light of human dimensions (64) and strategies are being implemented to help the species survive in the state of Orissa. The best population of gharial today is in the Chambal (64). Action to help the gharial in the Brahmaputra system is yet to be implemented. Nepal helped India during 1976 and 1977 in the latter's

gharial conservation programme by providing eggs. During 1978, with assistance from the Frankfurt Zoological Society, a captive management programme was established in the Royal Chitawan National Park. The project has supplied young gharial for restocking elsewhere in the kingdom. Today, gharial can again be seen in one of its former habitats: the Koshi River in eastern Nepal (66). Awareness campaigns in Pakistan and Bangladesh have remained active but sustained management efforts are yet to begin.

The 1990s may see reactivation of management efforts for gharial in India following an exhaustive indentification of the tasks and options (67).

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CONSERVATION OF THE SNAKES OF SRI LANKA

The island of Sri Lanka consists of three peneplains. The First Peneplain, covering the largest area, is from 0-122 m in elevation. The Second Peneplain which rises steeply from the inner edge of the First has elevations of 365-762 m. And the Third has a general elevation of 1529-1828 m and rises in places to 2938 m.

The Island and its surrounding waters support a highly diversified snake fauna. The most recent literature indicates 93 species of which 13 are sea snakes. Of the 80 species which live on the land area, 42 are endemic. Although the exact taxanomic status of some of these species in unclear and their endemicity therefore suspect, almost 45% of the total number of species seem to be endemic. This includes four endemic genera namely *Pseudotyphlops*, *Cercaspis*, *Balanophis* and *Haplocercus*. The genus *Aspidura* is known to occur in the Maldive Islands as well as Sri Lanka. However,it is now accepted that the single isolated record from the Maldive Islands represents an introduction by man and therefore it would seem appropriate to accept *Aspidura* as the fifth endemic genus. A number of snake species from Sri Lanka are geographical relicts of phylogenetic interest. This paper attempts to present, briefly, some problems relating to the conservation of the snakes of Sri Lanka with special emphasis on the endemic species.

A brief survey of the island's herpetofauna indicates that the rain forest areas of the Wet Zone and the Montane regions contain the highest rate of endemicity. It is also apparent that except in the legislatively protected areas most endemic snake species are confined to smaller habitat patches. These mainly constitute remnant forest patches of 10-20 ha in extent (Senanayake, 1982). With the absence

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A brief survey of the island's herpetofauna indicates that the rain forest areas of the Wet Zone and the Montane regions contain the highest rate of endemicity. It is also apparent that except in the legislatively protected areas most endemic snake species are confined to smaller habitat patches. These mainly constitute remnant forest patches of 10-20 ha in extent (Senanayake, 1982). With the absence

of large forest tracts in most areas the only suitable habitat consists of thick belts of forested land bordering water ways and amidst plantations. These are by no means in possession of the stable ecosystem of a rain forest, and are highly susceptible to human and climatic influences. However, there are a few taxon of endemic snakes which have adapted to life in disturbed habitats. This relates mainly to the genus *Aspidura* and the family *Uropeltidae*, each with 6 and 14 representatives respectively. These snakes are adapted to life in cultivated land, mainly tea estates. The high rate of diversity and abundance indicate a successful stand being made by these species.

The main problem affecting the survival of fauna in these small habitat patches is their isolation; thus creating the effect of an island. The species area curve (Mac Arthur and Wilson, 1963) shows the negative relationship between the number of species in a bounded area, and the area concerned. Also, the isolation of these habitats negates the chances of re-introduction of a species in the event of a local extinction. Thus, the continued preservation of these snakes is not assured.

The wet and montane areas of Sri Lanka which remained relatively undisturbed in the past, have during the last 100 to 150 years seen some major forest destruction. The main cause for this has been the planting of economically viable crops such as tea and rubber. In the upper montane regions cardamom is another cause for forest decimation. The combined effect of these plantations is proving to have severe and detrimental effects on the endemic fauna and flora of the island. Added to this, the wet zone of Sri Lanka has the highest population density with attendant industrialization and pollution.

Man's negative impact on the island's herpetofauna has become evident through the work of many recent naturalists. Erleden (1984) indicates that *Calotes versicolor*, or the common garden lizard, an indicator species of extremely disturbed habitat, has been steadily migrating inland and has at present reached certain areas of the upper montane forest.

This gives a clear indication of the extent of disturbance man has effected. Urbanization brings with it the additional problem of competitors in the form of generalized species and of predators. Two main predators whose effect on the herpetofauna has been ovelooked are the coucal, *Centropus sinensis parroti* and the mongoose *Herpestes sp.*

There remains of course the direct killing of snakes by man. The widespread and indiscriminate use of pesticides in Sri Lanka is now a matter of great concern among naturalists. Exploitation for skins remains an unknown factor; no records are available nor can an esti mate be formed as to the extent of the trade.

The main problem affecting the formulation of a conservation plan for the snakes of Sri Lanka is the absence of sufficient data on the distribution and relative abundance of these forms. Most records available are either out-dated or concentrate on the more generalized species. Recent works by herpetologists show the shifting of ranges of many species. In most cases this indicates the dwindling of former ranges and there are several species of which the existence has not been confirmed in recent times.

Therefore it is now of the utmost importance that a proper survey be carried out to map the distribution and abundance of the snakes of Sri Lanka. Hitherto unknown species await discovery, such as the new species of *Aspidura* found by Gans in 1982. A study would enable the identification of endangered species and their habitats in order to press for protective legislation. Although methods of species preservation such as captive breeding and re-introduction are being looked into as steps towards a conservation strategy, the only way of ensuring continued existence of the endemic snakes of Sri Lanka is strict habitat preservation.

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COMMENTARY

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NEW ADDITIONS TO THE HERPETOFAUNA OF PAKISTAN

Since the last publication of checklists of amphibians (Khan, 1976), lacertalians (Khan and Mirza, 1977) and ophidians (Khan, 1982), there have been several new additions to the herpetofauna of Pakistan. Descriptions of most of the new species are published in international herpetological journals which are generally not available to most of the zoologists and herpetologists in India and Pakistan. The following information pertaining to the new species is presented, specifically to fill this gap.

The table summarises the data, original references with type locality. The author will be thankful for any information pertaining to these taxa from Indian colleagues, since most of the type localities lie at the border or near the border of India and Pakistan. This information will help to chart the range of these forms to validate them, and will help establish their affinities.

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TABLE : Data pertaining to new species added to the herpetofauna of Pakistan

Name of the taxon	Type locality	Reference
Amphibians		
Rana (Paa) hazarensis	Datta, District Manshera, N.W.F.P.	Dubois and Khan, 1979.
Rana (Paa) barmoachensis	Barmoach, District Kotli, Azad Kashmir	Khan and Tasnim, 1989.
Lacertalian		
Crytodactylus dattanensis	Datta, District Manshera, N.W.F.P.	Khan, 1980.
Tenuidactylus indusoani	Pirpeahai, District Mianwali, Punjab	Khan, 1988.
Tenuidactylus montiumsalsorum	Salt Range, Punjab	Khan, 1989.
Tenuidactylus rohtasfortai	Rohtas Fort, Jhelum, Punjab	Khan and Tasnim, 1990.
Tenuidactylus kohsulaimanai	Sakhi Sarwar, D.G. Khan, Punjab	Khan, 1991
Ophidians		
Natrix sanctijohannis	Fort Maroat, District Bahawalnagar, Punjab	Khan, 1984
Bungarus sindanus razai	Makerwal, District Mianwali, Punjab	Khan, 1986

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